



# **Exploring the social dimensions of rural and remote microgrids in Australia's shift towards sustainable energy**

**by Farzan Tahir**

Thesis submitted in fulfilment of the requirements for the degree of

**Doctor of Philosophy**

under the supervision of Dr Scott Dwyer and Dr Scott Kelly

University of Technology Sydney  
Institute of Sustainable Futures

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## **Certificate of Original Authorship**

I, Farzan Tahir, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Institute of Sustainable Futures at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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## Thesis by compilation

In accordance with the Institute of Sustainable Future's thesis compilation guidelines, this dissertation is structured as a thesis by compilation, including chapters based on the published work of the author. Each chapter is distinct, highlighting the individual and novel work in the field of study. The list of journal articles is provided below:

**Paper 1:** Tahir, F., Dwyer, S., & Kelly, S. (2024). Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program. *Energy Research & Social Science*, 109, 103423.

**Paper 2:** Tahir, F., Dwyer, S., & Kelly, S. (2024). Embracing complexity: Microgrids and community engagement in Australia. *Energy Research & Social Science*, 118, 103811.

**Paper 3:** Tahir, F., Dwyer, S., Mey, F. & Kelly, S. (2025). Technology, People, and Place in Microgrids: Addressing Perceptions and Engagement challenges for a rural Australian town. *Energy Research and Social Science*, 127, 104305

## Declaration of co-authorship

The following table outlines the contributions of each co-author for the works that have been published or submitted to a journal as part of this thesis. The extent of each contribution has been mutually agreed upon by all parties involved.

### Paper 1.

In the case of Paper 1, *Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program*, the below parties agree that the nature of work and extent of contributions were as follows:

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## List of Acronyms

Multi-Criteria Decision Analysis	MCDA
Distributed Energy Resources	DERs
Community Energy	CE
Integrated Community Energy Systems	ICES
Clean Energy for Eternity	CEFE
Distribution Network Service Providers	DNSPs
Community Renewable Energy	CRE
Community Scale Batteries	CSB
small-scale photovoltaics	sPV
Low-Voltage Direct Current	LVDC
Home Energy Management Systems	HEMS
Mixed-Integer Linear Programming	MILP
Business Model Attributes	BMAs
Multi-Level Perspective	MLP
Community-Based Participatory Research	CBPR
Technology, People, Place, and Process	TPPP
Australian Bureau of Statistics	ABS
Heyfield Community Resource Centre	HCRC
Community Liaison Officer	CLO
Community Reference Group	CRG
Regional and Remote Community Reliability Fund	RRCRF
Australian Renewable Energy Agency	ARENA

Australian Energy Market Commission	AEMC
Australian Energy Market Operator	AEMO
National Electricity Market	NEM
New South Wales	NSW
Intergovernmental Panel on Climate Change	IPCC
Virtual Power Plants	VPPs
The National Centres for Environmental Information	NCEI
Conference of the Parties	COP 21
United Nations Framework Convention on Climate Change	UNFCC
International Renewable Energy Agency	IRENA
Sustainable Development Goals	SDGs
World Energy Outlook	WEO
International Energy Agency	IEA
Department of Climate Change, Energy, the Environment and Water	DCCEEW
Clean Energy Council	CEC
Giga Watt	GW
Clean Energy Finance Corporation	CEFC
Small-Scale Renewable Energy Scheme	SRES
Small Scale Technology Certificate	STCs
Coalition for Community Energy	C4CE
Citizens' Own Renewable Energy Network Australia	CORENA
Vocational Education and Training	VET
Institute of Sustainable Futures	ISF
Australian National University	ANU
Battery Energy Storage System	BESS
Compound Annual Growth Rate	CAGR
Institute of Electrical and Electronics Engineers	IEEE

United Nations Environment Program	UNEP
World Meteorological Organisation	WMO

## Abstract

As the global energy transition accelerates, renewable microgrids are emerging as a viable solution for enhancing energy resilience, reliability, and security. In Australia, they are primarily being developed through pilot projects and feasibility studies for remote and regional communities. While there is an extensive body of literature on the techno-economic aspects of microgrids, studies examining the social dimensions of their adoption and the role of community engagement remain limited. This thesis bridges this gap by examining the niche space inhabited by microgrids in Australia today.

This thesis employs a qualitative, mixed-method research approach, incorporating semi-structured interviews and surveys. It focused its research on cohorts of a national funding program that provided support to two dozen projects that represented more than one-hundred communities. The methodology features a systematic examination of the community engagement strategies used, the challenges faced, and the factors influencing social acceptance of microgrids at the local level.

It was found that there are strong drivers for microgrid adoption in Australia, including energy resilience, reliability, and clean energy integration. However, several barriers impede their progress, including the lack of a clear regulatory framework, financial constraints, uncertain business models, and challenges related to community engagement. A Community-Based Participatory Research (CBPR) framework is used to analyse the various community engagement strategies being used in Australian microgrid projects. This revealed that several critical steps in community engagement are often overlooked, thus hindering public participation and project success. The results

also underscore that a ‘one-size-fits-all’ engagement approach is ineffective, as each community presents unique challenges that require tailored engagement strategies. While resource-intensive engagement fosters greater community acceptance, poorly planned engagement strategies can lead to resistance and opposition to microgrid projects.

The insights derived from this research offer practical implications for community leaders, policymakers, community engagement practitioners, microgrid developers, and utilities. The findings emphasise the need for dedicated funding that incorporates community engagement as a core project component, ensuring that adequate resources are allocated for meaningful participatory processes. Additionally, the study highlights the importance of integrating community perspectives into policy frameworks and programs, helping microgrids to transition from niche innovations to mainstream energy solutions.

By addressing the gaps regarding the role of local communities in the success of microgrids, this research contributes to advancing clean energy solutions for Australians living in rural and remote communities. This can help position microgrids as a key component within the country’s energy transition.

# Chapter 1

## Introduction



Disruption by floods to the road connection to Aberdeen, Hunter Valley. NSW Surf Lifesaving.

Retrieved from <https://www.newcastle.edu.au/hippocampus/story/2023/what-australia-learned-from-devastating-floods>

*'A sustainable transformation is in fact, a new quest for new value systems' (Grin et al., 2010, p. 2).*

## 1.1 Introduction

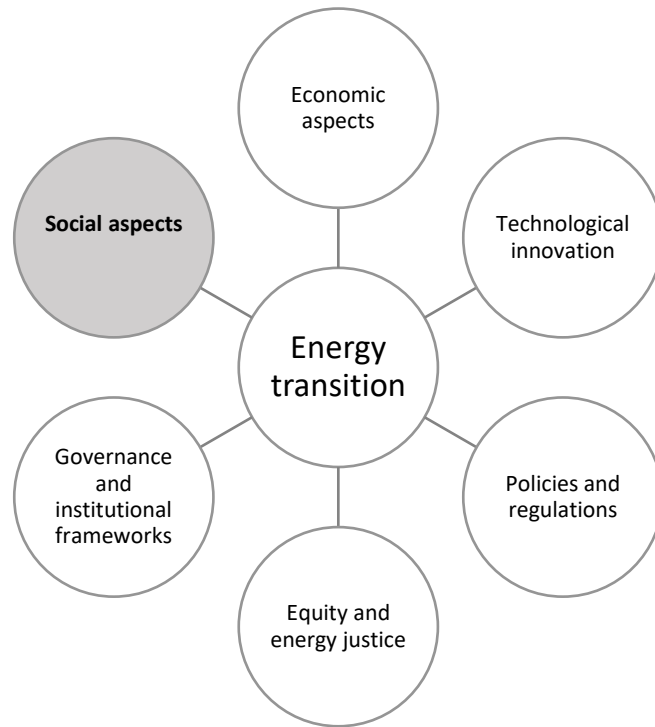
This thesis is situated within a pivotal period of global energy transition, driven by the urgent need to address the escalating impacts of climate change. These impacts are disproportionately affecting countries with minimal pollution and cleaner practices, underscoring the necessity for collective action among global stakeholders, including federal governments, researchers, policymakers, local communities, and energy providers. The burning of fossil fuels (coal, oil, and natural gas) for electricity generation, heating, and transportation constitutes a significant contributor to global greenhouse gas emissions, accounting for approximately three-quarters of the total (IPCC Report, 2021a). This substantial contribution is the urgent imperative to transition rapidly towards low-carbon energy sources to mitigate the escalating effects of climate change. Consequently, the concept of energy transition has gained considerable prominence in recent years, propelled by ambitious international targets for net carbon emission reductions over the coming decades.

While a universally accepted definition of energy transition remains absent in the academic literature, several recurring themes have emerged (Sovacool, 2016). Broadly defined, an energy transition constitutes a fundamental shift within an energy system, typically encompassing a transition to a different fuel source or a technological paradigm shift (Di Lucia & Ericsson, 2014; Jefferson, 2014; Parag & Janda, 2014). Some scholars conceptualise energy transition as a progressive shift toward cleaner energy systems dominated by renewable sources (Painuly, 2001; Sovacool, 2009) while others interpret it as a revolution involving disruptive changes in both technology and social practices (Martin, 2010; Miller et al., 2013).

The energy transition is a complex process, driven not solely by technological innovation and environmental policies, but also necessitating adjustments in political regulations, tariffs, pricing mechanisms, and concomitant shifts in the values, norms, behaviours,

attitudes, and practices of local communities (Giacovelli, 2022; Komendantova et al., 2018; Moloney et al., 2010; Sovacool, 2016; Ullman & Kittner, 2024) (see Figure 1). Local communities play a pivotal role in this transition, actively shaping energy policy and contributing to more successful project outcomes through their involvement (Giacovelli, 2022; Trombin et al., 2020). Fostering collaborative relationships between community representatives and project stakeholders enables community members to develop a deeper understanding of project objectives and relevant energy issues, facilitating informed participation in decision-making processes (Broska, 2021; Pidgeon et al., 2014).

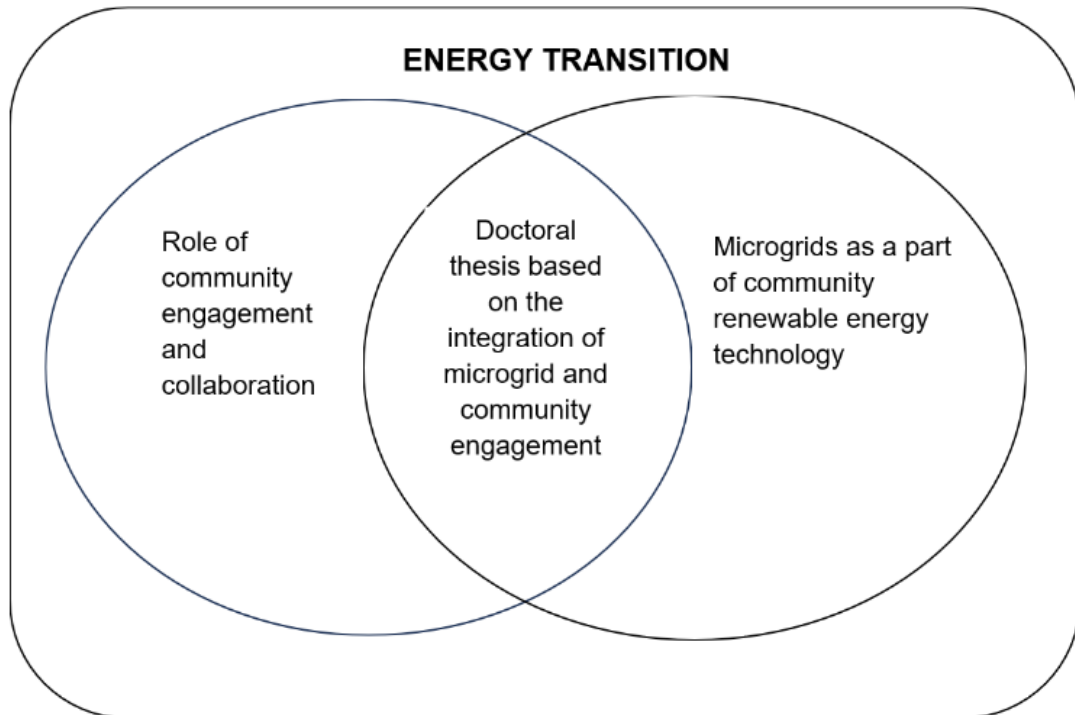
Despite the acknowledged significance of social dimensions in renewable energy technology adoption, the academic literature exhibits a notable gap in this area (Hoppe & De Vries, 2019; Sovacool, 2014). Research on social aspects is often relegated to the later stages of project development or conducted independently from technical research (Huijts et al., 2012; Wüstenhagen et al., 2007). Furthermore, limited research addresses the social acceptance of renewable energy technologies and the factors influencing it. This represents a critical area of inquiry, as it highlights the perspectives of local stakeholders, including government bodies, energy suppliers, and community leaders, towards new technologies. Understanding whether these stakeholders embrace innovation or perceive it as disruptive and threatening is important for the successful implementation of renewable energy projects (de Vries, 2017; Faber & Hoppe, 2013; Meadowcroft, 2009).



*Figure 1 Key Dimensions of Energy Transition*

This thesis investigates the social dimensions of microgrids, an emergent technological solution within the energy transition aimed at providing enhanced reliability, resilience, and sustainability in electricity supply for rural and remote communities. Building upon the existing literature on microgrids and community renewable projects, the thesis examines the role of local communities in microgrid deployment, analysing community engagement strategies and uncovering the factors influencing the social acceptance of these systems. Grounded in the Sustainability Transitions Management framework, this research utilises the Multi-Level Perspective (MLP) to examine the emergence of microgrids as a viable solution for delivering reliable electricity to remote and rural communities in Australia. Employing a qualitative research methodology with a mixed-methods approach, the thesis explores the complex interplay between microgrids, communities, and the broader energy transition within the Australian context. Figure 2 illustrates the conceptual positioning of this doctoral research within the wider context of energy transition. It highlights how the thesis integrates the role of community

engagement and collaboration with the technical dimension of microgrids as a community renewable energy solution.



*Figure 2 Emergence of the Thesis: Integration of Microgrids and Community Engagement*

This chapter provides an introduction to the thesis and is subdivided into 6 sections. Section 1.2 provides an in-depth analysis of the global context of the energy transition, focusing on the challenges of climate change. It also examines the global policies and initiatives to facilitate this energy transition. Section 1.3 highlights the challenges faced by regional and remote communities and explores emerging technologies essential for advancing the energy transition. This section also introduces technological advancements in solar, wind, Virtual Power Plants (VPPs), and microgrids, highlighting their potential benefits and their role in addressing the energy challenges faced by rural and remote communities. Section 1.4 addresses the role of community engagement and highlights the significance of community involvement in implementing microgrids. Section 1.5 presents microgrids as a potential solution for the energy transition, exploring their various definitions, applications, and the scale of their deployment globally. Section 1.6 outlines the research questions and research objectives that guide this thesis.

Section 1.7 concludes the chapter with a comprehensive overview of the thesis structure, which is further detailed in the subsequent chapters.

## 1.2 Global context: The climate crisis and need for action

Climate change has profoundly impacted the global landscape, leading to an increased frequency and intensity of natural disasters. These disasters have caused extensive damage to communities, economies, infrastructure, and overall well-being. Recent examples include floods in South Asia, typhoons in Southeast Asia, bushfires in the United States and Australia, and unprecedented heat waves in Europe, all of which have caused widespread devastation and prompted urgent calls for action (Disasters, 2024). To exemplify the magnitude of these impacts, the case of the United States provides a compelling illustration. The National Centres for Environmental Information (NCEI) reports that since the 1980s, the country has experienced 396 weather and climate-related disasters, resulting in thousands of fatalities and economic losses exceeding 2.78 trillion USD (National Centers for Environmental Information, 2024).

### 1.2.1 Global initiatives

On December 12, 2015, at COP 21 in Paris, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached an agreement aimed at combating climate change and accelerating the actions and investments required to achieve a sustainable and low-carbon future (United Nations Climate Change, 2024). The primary aim of the Paris Agreement was to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (Paris Accord Net Zero Emissions, 2020). The global energy sector has played a central role in addressing climate change, as highlighted by the International Renewable Energy Agency (IRENA), which reports that 73% of global greenhouse gas emissions originate from the energy sector (IRENA, 2023). This

necessitates an urgent transition within the energy sector towards reliance on sustainable energy resources. Table 1 illustrates a selection of global initiatives undertaken to address the climate change crisis, urging governments worldwide to take action and establish emission targets and goals.

*Table 1 Global Initiatives to deal with the Climate Crisis*

Global initiatives	Key features	References
<b>United Nations Sustainable Development Goals (SDGs)</b>	<ul style="list-style-type: none"> <li>In 2015, the United Nations initiated Sustainable Development Goals (SDGs), also known as the Global Goals, as a universal call to action to find ways to protect the planet and ensure that by 2030, all people enjoy peace and prosperity.</li> <li>Goal 13, based on climate action planning, requires individuals and the authorities to take urgent action to tackle climate change and its impacts by shifting to more renewable energy resources, making cities greener and more sustainable.</li> <li>Goal 7, ensuring access to affordable, reliable, sustainable and modern energy for all, is about ensuring that people everywhere have access to clean and reliable energy.</li> </ul>	(UN Sustainable Development Goals, 2025)
<b>Climate Action for Jobs</b>	<ul style="list-style-type: none"> <li>This initiative has developed a roadmap and regional strategies prioritising employment and well-being in the transition to a sustainable, green economy.</li> </ul>	(Climate Action for Jobs, 2025)
<b>Cool Coalition</b>	<ul style="list-style-type: none"> <li>This global initiative unites efforts to deliver efficient and climate-friendly cooling solutions, emphasising their integration into enhanced national climate plans.</li> <li>The coalition showcases innovative approaches, such as "cooling paper," which helps regulate building temperatures</li> </ul>	(Cool Coalition, 2025)
<b>The Energy Efficiency Global Alliance</b>	<ul style="list-style-type: none"> <li>This coalition of governmental, corporate, and non-governmental leaders advocates for accelerated energy efficiency improvements.</li> <li>It assists countries in developing roadmaps to enhance energy efficiency, setting a target of a 3 per cent annual improvement</li> </ul>	(The Energy Efficiency Global Alliance, 2025)
<b>Powering Past Coal Alliance:</b>	<ul style="list-style-type: none"> <li>This alliance, comprising countries, investors, utilities, and cities, aims to phase out coal as an energy source.</li> <li>It fosters political and industrial consensus on retiring coal early and eliminating coal financing in the energy sector.</li> </ul>	(Powering Past Coal Alliance, 2025)
<b>Intergovernmental Panel on</b>	<ul style="list-style-type: none"> <li>Established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO), the IPCC provides scientific</li> </ul>	(IPCC Report, 2021b)

<b>Climate Change (IPCC)</b>	assessments on climate change, its impacts, and future risks. <ul style="list-style-type: none"> <li>• Its reports guide international climate negotiations and policy decisions by synthesising the latest research on mitigation, adaptation, and pathways to limit global warming.</li> </ul>	
<b>Conference of the Parties (COP)</b>	<ul style="list-style-type: none"> <li>• The COP is the decision-making body of the United Nations Framework Convention on Climate Change (UNFCCC), meeting annually to review global progress in tackling climate change.</li> <li>• Major agreements include the Kyoto Protocol (COP3, 1997) and the Paris Agreement (COP21, 2015), which set legally binding and voluntary commitments to reduce emissions and accelerate the transition to renewable energy.</li> <li>• Recent COPs (such as COP26 in Glasgow and COP28 in Dubai) emphasised net-zero targets, phasing down fossil fuels, and scaling up climate finance for developing nations.</li> </ul>	(United Nations Climate Change, 2025)

In response to global initiatives aimed at mitigating climate change (a selection of which are outlined in Table 1), there has been a substantial increase in research evaluating the technical feasibility and economic viability of renewable energy resources. The World Energy Outlook (WEO), widely recognised as a leading authority on energy analysis and projections, envisions a 2030 energy system characterised by a significantly greater role for clean technologies (IEA 50, 2023a). Key projections indicate a nearly tenfold increase in electric vehicles worldwide and a rise in the share of renewables in the global electricity mix to nearly 50%, up from approximately 30% in 2023. Consequently, the share of fossil fuels in the global energy supply, which has remained at approximately 80% for decades, is projected to decline to 73% by 2030 (IEA 50, 2023b).

### 1.3 Australia’s climate challenges and shift towards sustainable energy

In recent years, Australia has joined the growing number of nations experiencing unprecedented impacts resulting from climate change. These include the 2019–2020 bushfires, which resulted in estimated losses of 100–200 billion AUD, as well as floods,

storms, and an increased frequency of heat waves. Data from the Bureau of Meteorology indicate a 1.51°C rise in average temperatures from 1910 to 2023, while surrounding ocean temperatures have increased by 1°C since 1910 (Bureau of Meteorology, 2024). Furthermore, heavy rainfall events have intensified by at least 10% since 1979, and both the duration and frequency of heat waves have increased since 1970, reflecting a persistent warming trend. A survey conducted by the Climate Council revealed that a substantial majority (84%) of Australians report being directly affected by at least one climate-related disaster since 2019 (Climate Council, 2024). These disasters include heatwaves (71%), floods (45%), bushfires (43%), droughts (37%), destructive storms (35%), and landslides (8%) (Climate Council, 2024). These climate-related events have spurred policymakers to undertake significant reforms in energy policy, transitioning towards more sustainable solutions for energy generation, transmission, and distribution.

### 1.3.1 Australian initiatives in the energy transition

Australia has been at the forefront of the global energy transition, with federal and local governments implementing numerous measures to address climate change (Berka & Creamer, 2018). Australia is committed to reducing greenhouse gas emissions by 43% below 2005 levels by 2030 and achieving net-zero emissions by 2050. These targets are aligned with the Paris Agreement's goal of limiting the increase in average global temperatures to well below 2°C and pursuing efforts to restrict warming to below 1.5°C (DCCEEW, 2022). The Net Zero Plan outlines Australia's strategy for achieving net-zero greenhouse gas emissions by 2050, detailing government priorities and policies to reduce emissions while supporting investments in low-emissions and renewable energy projects (DCCEEW, 2025).

Despite fossil fuel sources accounting for 65% of total electricity generation in 2023 (coal 46%, gas 17%, and oil 2%), coal-fired power generation has exhibited a downward trend (DCCEEW, 2024a). Energy data reports indicate that 16GW of thermal generation,

representing approximately 61% of the current coal fleet in the National Electricity Market (NEM), is expected to retire over the next two decades (State of the energy market, 2024). The Australian NEM is committed to transitioning from a centralised system dominated by large-scale fossil fuel (coal and gas) generation to a decentralised network comprising smaller, widely distributed energy resources. This includes wind and solar generators, hydroelectric generation, grid-scale batteries, and demand response systems (State of the energy market, 2024). The Clean Energy Council (CEC) report reveals a significant expansion of renewable energy capacity, with 5.9 GW added in 2023, an increase from 5 GW in 2022. Of this, 3.1 GW was attributed to rooftop solar installations, up from 2.7 GW in 2022. Furthermore, new financial commitments to large-scale storage reached 4.9 billion AUD in 2023, compared to 1.9 billion AUD in 2022 (Clean Energy Council, 2024). Renewable energy generation is also on the rise in Australia, contributing 35% of total electricity generation in 2023, primarily from solar (16%), wind (12%), and hydro (6%) (Clean Energy Council, 2024).

Australian federal and state governments have allocated substantial funding to support the energy transition and achieve their net-zero targets. The Australian Government is actively driving the development of the nation's future energy system through several key initiatives focused on job creation, reducing electricity costs, and meeting emissions reduction targets.

Since 2012, the Australian Renewable Energy Agency (ARENA) has played a crucial role in fostering innovation within the renewable energy sector (ARENA, 2023a). ARENA has supported 663 projects with 2.25 billion AUD in grant funding, leveraging a total investment of nearly 9.75 billion AUD in Australia's renewable energy industry (ARENA, 2023a). The Clean Energy Finance Corporation (CEFC) has also committed approximately 10 billion AUD in finance to over 1,000 renewable energy projects (CEFC, 2023).

Collaborations between industry and research institutions have also successfully secured government funding. For instance, the RACE for 2030 Cooperative Research Centre received 68.5 million AUD from the Federal Government, matched by industry contributions, to conduct research into reliable, affordable, and clean energy solutions. Table 2 provides an overview of other notable renewable energy initiatives and funding programs; however, it represents a selected sample rather than an exhaustive list of all available programs.

Table 2 Australian renewable energy initiatives

Renewable energy initiatives		Primary objectives	References
<b>Renewable Targets</b>	<b>Energy</b>	<ul style="list-style-type: none"> <li>To meet the energy targets according to the UNFCCC Paris Agreement</li> <li>To increase the large-scale renewable energy generation by 33,000GWh by 2020</li> <li>To further promote renewable electricity generation, focusing on reducing greenhouse gas emissions in the energy sector</li> </ul>	(Department of Industry, Science, 2020)
<b>Paris Accord</b>		<ul style="list-style-type: none"> <li>To reduce carbon emissions by 26 – 28% in 2030 compared to emissions in 2005</li> </ul>	(United Nations Climate Change, 2024)
<b>Australian Power Agency</b>	<b>Local</b>	<ul style="list-style-type: none"> <li>Increase the number of community energy projects</li> <li>Regional communities in Australia are also sharing the direct benefits of renewable energy technologies</li> </ul>	(The Australia Institute, 2021)
<b>Powering plan</b>	<b>Australia</b>	<ul style="list-style-type: none"> <li>Aims to create jobs, reduce pressure on energy bills, and cut emissions by 43% of 2005 levels by 2030</li> </ul>	(Powering Australia, 2024)
<b>Net Zero Plan</b>		<ul style="list-style-type: none"> <li>This plan outlines and expands on the nation's commitment to address climate change</li> <li>This plan aims to set out government priorities, publish policies and map out actions to reduce emissions and enhance investment in renewable activities</li> </ul>	(Net Zero Plan, 2024)
<b>Rewiring the Nation</b>		<ul style="list-style-type: none"> <li>Commits \$20 billion in low-cost financing to modernise Australia's electricity grid</li> <li>This investment will fund essential transmission infrastructure projects, enabling Australians to have a more reliable and renewable energy system.</li> <li>The initiative also supports the delivery of affordable and dependable clean energy to urban, regional, and remote communities, contributing to the country's long-term target of net zero emissions by 2050</li> </ul>	(DCCEEW, 2024b)
<b>Small-scale Renewable Scheme (SRES)</b>	<b>Energy</b>	<ul style="list-style-type: none"> <li>This scheme encourages households and businesses to adopt renewable energy technologies such as rooftop solar panels, solar water heaters, and small-scale wind or hydro systems.</li> </ul>	(DCCEEW, 2025)

	<ul style="list-style-type: none"> <li>System owners can create small-scale technology certificates (STCs)<sup>1</sup> upon installing eligible systems, incentivising the uptake of these technologies</li> </ul>	
<b>Capacity Investment Scheme</b>	<ul style="list-style-type: none"> <li>This scheme aims to accelerate investment in renewable energy generation such as wind, solar</li> <li>Aims to increase investment in clean dispatchable capacity such as battery storage</li> <li>Establishes a long-term revenue stability framework that mitigates financial risks for investors and fosters greater confidence in sustainable energy projects</li> </ul>	(DCCEEW Capacity Investment Scheme, 2024)
<b>New Vehicle Efficiency Standards</b>	<ul style="list-style-type: none"> <li>Aim to reduce fuel costs for consumers while providing cleaner vehicle options in Australia.</li> <li>Increase the availability of efficient, modern vehicles</li> </ul>	(New Vehicle Efficiency Standard, 2024)
<b>Solar energy rebates and incentives</b>	<ul style="list-style-type: none"> <li>Aim to enhance solar uptake in Australian states.</li> <li>Offer monetary rewards for households and small businesses to adopt small-scale renewable systems.</li> </ul>	(Solar Energy Rebates, 2024)

The selection of initiatives outlined in Table 2 illustrates Australia's progress in renewable energy policy development, with various states implementing significant measures to establish ambitious policies that drive the energy transition. The Australian energy transition strategy emphasises the importance of enhancing education, awareness, and institutional capacity for the integration of clean energy (Clean Energy Council, 2024). This socially inclusive approach aligns with the Sustainable Development Goals (SDGs) and the Paris Agreement, promoting a just and equitable transition to a low-carbon future.

Table 3 provides details on research institutes, non-profit organisations, and community energy groups dedicated to implementing socially inclusive strategies for a clean energy

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<sup>1</sup> To promote the adoption of renewable energy, the Australian Government offers incentives in the form of Small-Scale Technology Certificates (STCs). These certificates are granted to individuals or businesses upon the installation of eligible small-scale renewable energy systems. STCs contribute to achieving renewable energy targets and play a key role in reducing carbon emissions.

transition; however, it represents only a selection of initiatives intended to illustrate the diversity of approaches rather than provide an exhaustive list.

Table 3: A selection of initiatives to raise awareness and involve communities

Selection of initiatives	Details	References
<b>Coalition for Community Energy (C4CE)</b>	<ul style="list-style-type: none"> <li>Envisioning community energy as a pivotal force in Australia's renewable and sustainable energy landscape</li> <li>Local groups and projects lead in creating, developing, owning, and managing renewable initiatives, directly benefiting from them</li> </ul>	(Coalition for Community Energy, 2025)
<b>Hepburn Wind</b>	<ul style="list-style-type: none"> <li>Australia's first community-owned wind farm, showcasing a decade of successful operation.</li> <li>Pioneering community-owned wind farm in Australia, serving as a model for future renewable energy projects.</li> </ul>	(Hepburn Energy, 2025)
<b>CORENA</b>	<ul style="list-style-type: none"> <li>Empowering Australians to combat climate emergencies through renewable energy funds supporting carbon-reduction projects.</li> <li>Providing zero-interest loans and technical assistance to eligible non-profits for climate initiatives, with repayments made through energy cost savings.</li> </ul>	(CORENA, 2025)
<b>Bendigo Sustainability Group</b>	<ul style="list-style-type: none"> <li>Independent and community-focused, fostering a culture of understanding, education, and inspiration to build a sustainable future together.</li> <li>Significant contributions to regional sustainability achieved through dedicated action groups and community-driven projects.</li> </ul>	(Bendigo Sustainability Group, 2025)
<b>Powering Skills Organization</b>	<ul style="list-style-type: none"> <li>Ensuring Australia's Vocational Education and Training (VET) sector delivers industry-driven outcomes for learners and employers in the energy sector.</li> <li>Utilising the new Data Dashboard for insights on industry trends, occupations, training enrolments, completions, and employer-sponsored apprenticeships.</li> </ul>	(PSO, 2025)
<b>Research Institutes</b>	<ul style="list-style-type: none"> <li>Pivotal in Australia's clean energy transition, bridging academic knowledge, policy development, and real-world implementation.</li> </ul>	(Australian National University, 2025; Institute of Sustainable Futures, 2025; Monash University, 2025;

	<ul style="list-style-type: none"> <li>• Providing evidence for policymaking, driving technological innovation, and training future experts.</li> <li>• Providing practical, sustainable, and socially equitable energy solutions through interdisciplinary collaboration and stakeholder engagement.</li> <li>• Research institutes such as ISF, Centre for Water, Energy and Waste, Net Zero Institute, Victoria Energy Policy Centre, ANU Energy Change, Monash Energy Institute, etc. are playing a crucial role in advancing a sustainable future and driving the energy transition through research, innovation, and policy development.</li> </ul>	University of Sydney, 2025; Victoria Energy Policy Centre, 2025)
<b>Blue Mountains Renewable Energy Co-op</b>	<ul style="list-style-type: none"> <li>• Volunteer group from the Blue Mountains dedicated to developing community-owned renewable energy projects in the unique World Heritage area.</li> <li>• Inspiring and supporting local, community-owned renewable energy generation and energy efficiency initiatives to benefit both the environment and the community.</li> </ul>	(Blue Mountains Renewable Energy Co-op, 2025)

## 1.4 Electricity issues in the regional and remote communities

According to the IEA, approximately 750 million people worldwide still lack access to electricity (IEA, 2023). Providing reliable electricity in these areas presents considerable challenges due to the elevated costs associated with transmission and distribution infrastructure (AEMC, 2023; ARENA, 2023a; Ekistica, 2018; Lu et al., 2015). Furthermore, communities located on the fringe of electricity grids often experience voltage imbalances, voltage fluctuations, and instability in system frequency (ARENA, 2024). Electricity costs in these regions are also typically high, primarily due to the expense of fuel required for local power generation, which often relies on diesel and natural gas (Australian Renewable Energy Agency, 2024).

### 1.4.1 Remote communities in Australia

Australia, the world's sixth-largest country by landmass, possesses a relatively small population of 27 million, particularly when compared to Brazil (214 million) and India (1.4

billion). The population outside major metropolitan areas is highly dispersed, with 8.5 million people residing in rural towns, regional areas, villages, and remote regions (Australian Bureau of Statistics, 2023). Approximately 500,000 people, or 2% of the Australian population, live in remote areas without access to the electricity grid (Australian Renewable Energy Agency, 2024; Khodayar, 2017). Connecting these off-grid communities to the national electricity network is often deemed unfeasible due to the high costs associated with extending transmission and distribution infrastructure (AEMC, 2023). Despite their relatively small population size, these communities account for over 6% of Australia's total electricity consumption, primarily due to energy-intensive activities such as agricultural processing, mining, dairy farming, telecommunications, and desalination operations (ARENA, 2024). A survey conducted by the Clean Energy Council (CEC) revealed that individuals residing in rural and remote communities (60%) are significantly more likely to have experienced one or more flood events compared to those in inner metropolitan (42%) and outer metropolitan (31%) areas (Clean Energy Council, 2024). This vulnerability underscores the need for improved sustainable energy solutions in these regions, where an unreliable electricity supply can hinder economic development and community well-being.

Distributed Energy Resources (DERs) have been widely recognised as a viable solution for electrifying remote or underserved regions (Asmus, 2010; Gumerman et al., 2003; More Microgrids, 2009; C. Wang et al., 2018). By utilising renewable energy sources for electricity generation, isolated communities and industries can reduce energy costs, enhance energy security and reliability, and mitigate carbon emissions by decreasing reliance on diesel or natural gas. Various renewable energy technologies, including solar, wind, geothermal, microturbines, battery energy storage systems (BESS), and microgrids, can support off-grid users independently or in combination with advanced energy management systems and smart controls (Prevedello & Werth, 2021).

However, integrating intermittent renewable energy sources into existing centralised power systems presents challenges. These challenges include voltage and frequency fluctuations, grid synchronisation issues, network augmentation requirements, protection issues associated with bi-directional power flow, and the need for effective energy storage solutions (Agarwal & Mittal, 2011; Gui & Iain MacGill, 2018; R. H. Lasseter, 2002). To address these challenges, decentralised solutions have emerged, including microgrids (Farrelly & Tawfik, 2020), Virtual Power Plants (VPPs) (van Summeren et al., 2020), community batteries (Comello & Reichelstein, 2019), electric vehicles (Dwyer et al., 2021), stand-alone PV systems (S. Pati et al., 2017), and biomass power systems (Middelhoff et al., 2021).

## 1.5 Microgrids – a promising solution for rural electrification

Microgrids have emerged as a promising solution for integrating renewable energy resources into the electricity grid and addressing the challenges of providing reliable and sustainable electricity access, particularly in rural and remote communities (Basak et al., 2012; Hirsch et al., 2018; R. H. Lasseter, 2002; Shahidehpour & Clair, 2012). While multiple definitions exist (see Chapter 2), microgrids are commonly defined as "a group of interconnected loads and distributed energy resources within a defined electrical boundary that operates as a single controllable entity, capable of connecting or disconnecting from the main grid and operating independently in islanded mode" (Guerrero M. Josep & Kandari Ritu, 2021; Olivares et al., 2014; Planas et al., 2015; Ton & Smith, 2012; Warneryd et al., 2020). Microgrids offer several advantages, including improved electricity resilience (Lu et al., 2015), reliability (Ilindala et al., 2007; Wu & Sansavini, 2020) and security (Onu et al., 2023; Sovacool & Mukherjee, 2011). In rural areas, microgrids can provide cost-effective electricity while mitigating the need for extensive and expensive transmission and distribution infrastructure (Daniel Schnitzer, Deepa Shinde Lounsbury, Juan Pablo Carvallo et al., 2014; Thorpe, 2015; Wei & Chen,

2019). The terms microgrid and minigrid are occasionally used interchangeably (as discussed in detail in Section 2.1.1.4), although they in fact refer to distinct types of systems (Perez-DeLaMora et al., 2021).

The global microgrid market is experiencing significant growth, with governments worldwide supporting and financing microgrid projects (Ali et al., 2017; Mariam et al., 2016; Y. Wang et al., 2020). While Australia's microgrid market is currently niche, with many projects in the pilot or feasibility stage, significant funding has been allocated to support its development (ARENA, 2023b; Department of Climate Change, Energy, the Environment, 2022).

Microgrid applications are diverse, encompassing military installations, research laboratories, university campuses, mining and tourism towns, and residential and industrial communities (Gui et al., 2017; Kaczmarek, 2022; Warneryd et al., 2020). The ability to operate in islanded mode is a primary feature of microgrids, enhancing community resilience to catastrophic events such as storms, bushfires, and other natural disasters (Microgrid Knowledge, 2015). For example, Japan's Fujisawa Sustainable Smart Town Community Microgrid was designed to provide electricity to the Sendai Uni Hospital during the 2011 tsunami (IEEE Spectrum, 2021).

## 1.6 The Role of Local Communities in Shaping the Energy Transition: Research Aims and Questions

The successful implementation of the energy transition necessitates a profound transformation in community actions, behaviours, practices, attitudes, and perspectives (Alvial-Palavicino et al., 2011; Komendantova et al., 2018; Miller et al., 2013; Radtke & Scherhauser, 2022; Soeiro & Ferreira Dias, 2020; Ternes et al., 2024). Community participation in energy projects enhances awareness of emerging technologies, available energy rebates, project funding opportunities, and existing energy policies.

In addition to community participation, social acceptance is crucial for the successful implementation of new technologies and projects, as local opposition can significantly hinder progress (Koirala et al., 2018). Effective and resource-intensive community engagement is vital in fostering local acceptance of renewable energy technologies (Hicks & Ison, 2018; Seyfang & Smith, 2007).

### 1.6.1 Microgrids and Community Engagement

Despite the critical role of local communities in energy projects, research on the social dimensions of renewable energy technologies remains limited compared to studies on technical and economic aspects. This thesis focuses on microgrids, and the existing literature reveals a significant gap in understanding the social dimensions associated with microgrid development and the role of local communities in microgrids implementation. The successful deployment of microgrids depends not only on their techno-economic feasibility but also on a comprehensive understanding of social factors to facilitate their mainstream adoption (Adil & Ko, 2016; Akinyele et al., 2018; Perez-DeLaMora et al., 2021; Pullins, 2019; Ustun et al., 2011).

This thesis aims to address this gap by investigating the role of social factors in microgrid implementation, with a particular emphasis on the role of local communities in microgrid development. It seeks to understand the significance of community engagement in microgrid projects, highlighting the importance of including the local community in decision-making processes and understanding community perceptions surrounding microgrids. The thesis objectives are outlined below:

- Understanding the role of microgrids in the energy transition, focussing on understanding drivers, barriers and opportunities regarding microgrid activities in Australia
- Emphasising the role of community engagement in the microgrid-related projects, and the importance of community engagement activities in the projects

- Understanding the social acceptance around microgrids
- Evaluating the community engagement strategies and understanding whether engagement leads to acceptance or conflicts

Proposing a guide for the policy makers and community engagement professionals to guide future microgrid activity.

This thesis aims to address the following overarching research question, which is further subdivided into four specific research questions

**How can a sustainable transition framework guide the advancement of microgrids in Australia, highlighting the pivotal role of community engagement?**

**Question 1:** What are the major barriers and opportunities in microgrid-related studies in Australia, and how do these compare to those assumed in the international literature?

**Question 2:** How can policy makers, organisations and community engagement professionals get better outcomes from engaging the community in microgrid projects?

**Question 3:** Based on the research on Australian microgrids, what will be the implications of including local communities in the decision-making process on the energy policy involving microgrids and funding potential?

**Question 4:** Are community engagement strategies in microgrids supporting social cohesion and public acceptance or creating conflicts in the local community?

## 1.7 Thesis Outline

This thesis investigates the complexities of integrating microgrids into rural and remote communities in Australia as part of the nation's energy transition. It analyses and interprets data gathered from nationwide research on microgrid projects in these communities, presenting findings on the key drivers, barriers, and opportunities associated with their implementation. The thesis comprises eight chapters. Chapter 1

introduces the global context of the energy transition, providing an overview of microgrids, including their definitions, complexities, global market share, and the importance of social research in microgrid development. It also outlines the research objectives and questions guiding this investigation. Chapter 2 reviews the extant literature on various aspects of microgrids, examining current research and emerging developments while identifying gaps, particularly concerning the social dimensions of microgrids, which this thesis aims to address. Chapter 3 delineates the research methodology and design, encompassing the conceptual and analytical frameworks and the strategies employed in the study.

Chapters 4, 5, and 6 present the core arguments and findings of this study, directly addressing the overarching research questions. These chapters draw upon a series of published manuscripts developed as part of this research. Chapter 7 synthesises the overall findings, highlighting research limitations and providing recommendations to foster microgrid deployment in Australia. Finally, Chapter 8 concludes the thesis by summarising the key findings, discussing their implications, and proposing directions for future research.

## 1.8 References

- Adil, A. M., & Ko, Y. (2016). Socio-technical evolution of Decentralized Energy Systems: A critical review and implications for urban planning and policy. *Renewable and Sustainable Energy Reviews*, 57, 1025–1037. <https://doi.org/10.1016/j.rser.2015.12.079>
- AEMC. (2023). *National Electricity Market*. <https://www.aemc.gov.au/energy-system/electricity/electricity-system/NEM>
- Agarwal, M., & Mittal, A. (2011). Micro Grid Technological Activities Across The Globe: A Review. *International Journal of Research and Reviews in Applied Sciences (IJRRAS)*, 7(2), 147–152.

- Ajaz, W., & Bernell, D. (2021). California's adoption of microgrids: A tale of symbiotic regimes and energy transitions. *Renewable and Sustainable Energy Reviews*, 138. <https://doi.org/10.1016/j.rser.2020.110568>
- Akinyele, D., Belikov, J., & Levron, Y. (2018). Challenges of Microgrids in Remote Communities: A STEEP Model Application. *Energies*, 11, 432. <https://doi.org/10.3390/en11020432>
- Ali, A., Li, W., Hussain, R., He, X., Williams, B., & Memon, A. (2017). Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China. *Sustainability*, 9(7), 1146. <http://dx.doi.org/10.3390/su9071146>
- Alvial-Palavicino, C., Garrido-Echeverría, N., Jiménez-Estévez, G., Reyes, L., & Palma-Behnke, R. (2011). A methodology for community engagement in the introduction of renewable based smart microgrid. *Energy for Sustainable Development*, 15(3), 314–323. <https://doi.org/10.1016/j.esd.2011.06.007>
- ARENA. (2023a). *Australian Renewable Energy Agency*. <https://arena.gov.au/>
- ARENA. (2023b). *Regional Microgrids Funding*. <https://arena.gov.au/funding/rmp/>
- ARENA. (2024). *Microgrids: Cheaper, cleaner, reliable energy for remote communities*. <https://arena.gov.au/blog/microgrids-cheaper-cleaner-reliable-energy-for-remote-communities/>
- Asmus, P. (2010). Microgrids, Virtual Power Plants and Our Distributed Energy Future. *Electricity Journal*, 23(10), 72–82. <https://doi.org/10.1016/j.tej.2010.11.001>
- Australian Bureau of Statistics. (2023). *Heyfield*. <https://abs.gov.au/census/find-census-data/quickstats/2021/SAL21179>
- Australian National University. (2025). *Institute of Climate, Energy, and Disaster Solutions*. <https://iced.s.anu.edu.au/>

- Australian Renewable Energy Agency. (2024). *Off Grid*. <https://arena.gov.au/renewable-energy/off-grid/>
- Basak, P., Chowdhury, S., Halder Nee Dey, S., & Chowdhury, S. P. (2012). A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid. *Renewable and Sustainable Energy Reviews*, 16(8), 5545–5556. <https://doi.org/10.1016/j.rser.2012.05.043>
- Bendigo Sustainability Group. (2025). *About us*. <https://www.bsg.org.au/>
- Berka, A. L., & Creamer, E. (2018). Taking stock of the local impacts of community owned renewable energy: A review and research agenda. *Renewable and Sustainable Energy Reviews*, 82(October 2016), 3400–3419. <https://doi.org/10.1016/j.rser.2017.10.050>
- Blue Mountains Renewable Energy Co-op. (2025). *Home*. <https://bmrenew.org/>
- Broska, L. H. (2021). It's all about community: On the interplay of social capital, social needs, and environmental concern in sustainable community action. *Energy Research and Social Science*, 79(June), 102165. <https://doi.org/10.1016/j.erss.2021.102165>
- Bureau of Meteorology. (2024). *State of the Climate*. <https://www.bom.gov.au/state-of-the-climate/australias-changing-climate.shtml#:~:text=Australian%20temperatures%20and%20global%20warming,to%20broader%20global%20warming%20levels>.
- Busch, G. (2017). A spatial explicit scenario method to support participative regional land-use decisions regarding economic and ecological options of short rotation coppice (SRC) for renewable energy production on arable land: case study application for the Göttingen dist. *Energy, Sustainability and Society*, 7(1). <https://doi.org/10.1186/s13705-017-0105-4>
- CEFC. (2023). *Record-breaking year of investments* <https://www.cefc.com.au/>

Clean Energy Council. (2024). *Clean Energy Australia*.  
<https://cleanenergycouncil.org.au/getmedia/0cb12425-37ab-479e-9a4b-529622cc9c02/clean-energy-australia-2024.pdf>

Climate Action for Jobs. (2025). *Vision and Mission*. <https://www.climateaction4jobs.org/>

Climate Council. (2024). *Climate Council*.  
[https://www.climatecouncil.org.au/resources/survey-results-climate-fuelled-disasters-cause-australians-to-fear-permanent-loss-of-homes/#:~:text=The%20overwhelming%20majority%20\(84%25\),%25\)%20and%20land slides%20\(8%25\).](https://www.climatecouncil.org.au/resources/survey-results-climate-fuelled-disasters-cause-australians-to-fear-permanent-loss-of-homes/#:~:text=The%20overwhelming%20majority%20(84%25),%25)%20and%20land slides%20(8%25).)

Coalition for Community Energy. (2025). *About C4CE*. <https://c4ce.net.au/>

Comello, S., & Reichelstein, S. (2019). The emergence of cost effective battery storage. *Nature Communications*, 10(1), 1–9. <https://doi.org/10.1038/s41467-019-09988-z>

Cool Coalition. (2025). *Overview and history*. <https://coolcoalition.org/about/overview-and-history/>

CORENA. (2025). *Introduction*. <https://corenafund.org.au/>

Daniel Schnitzer, Deepa Shinde Lounsbury, Juan Pablo Carvallo, R. D., Jay Apt, and D. M. K., Schnitzer, D., Deepa, S., Carvalo, J. P., Ranjit, D., Jay, A., & Daniel, K. (2014). Microgrids for Rural Electrification : A critical review of best practices based on seven case studies Microgrids for Rural Electrification : A critical review of best practices. *United Nations Foundation*, 122.

DCCEEW. (2022). *Energy Supply*. <https://www.energy.gov.au/government-priorities/energy-supply/#:~:text=Most of our electricity is,homes for heating and cooking.>

DCCEEW. (2024a). *Electricity Generation*. <https://www.energy.gov.au/energy-data/australian-energy-statistics/electricity->



- Faber, A., & Hoppe, T. (2013). Co-constructing a sustainable built environment in the Netherlands—Dynamics and opportunities in an environmental sectoral innovation system. *Energy Policy*, 52, 628–638.
- Farrelly, M. A., & Tawfik, S. (2020). Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renewable and Sustainable Energy Reviews*, 117(October 2019), 109491. <https://doi.org/10.1016/j.rser.2019.109491>
- Giacovelli, G. (2022). Social Capital and Energy Transition: A Conceptual Review. *Sustainability*, 14(15). <https://doi.org/10.3390/su14159253>
- Guerrero M. Josep, & Kandari Ritu. (2021). *Microgrids: Modeling, Control and Applications*. Academic Press.
- Gui, E. M., Diesendorf, M., & MacGill, I. (2017). Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renewable and Sustainable Energy Reviews*, 72(October 2016), 1355–1365. <https://doi.org/10.1016/j.rser.2016.10.047>
- Gui, E. M., & Iain MacGill. (2018). Typology of future clean energy communities: An exploratory structure, opportunities, and challenges. *Energy Research and Social Science*, 35, 94–107. <https://doi.org/10.1016/j.erss.2017.10.019>
- Gumerman, E. Z., Bharvirkar, R. R., LaCommare, K. H., & Marnay, C. (2003). *Evaluation Framework and Tools for Distributed Energy Resources*. <https://doi.org/10.2172/816218>
- Hepburn Energy. (2025). *Introduction*. <https://www.hepburnenergy.coop/>
- Hicks, J., & Ison, N. (2018). An exploration of the boundaries of ‘community’ in community renewable energy projects: Navigating between motivations and context. *Energy Policy*, 113, 523–534. <https://doi.org/10.1016/j.enpol.2017.10.031>

- Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and Sustainable Energy Reviews*, 90(September 2017), 402–411. <https://doi.org/10.1016/j.rser.2018.03.040>
- Hoppe, T., & De Vries, G. (2019). Social Innovation and the Energy Transition. *Sustainability*, 11(1). <https://doi.org/10.3390/su11010141>
- Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, 16(1), 525–531.
- IEA. (2023). *Access to Electricity*. <https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity>
- IEA 50. (2023a). *World Energy Outlook*. <https://www.iea.org/news/the-energy-world-is-set-to-change-significantly-by-2030-based-on-today-s-policy-settings-alone>
- IEA 50. (2023b, October 24). *The energy world is set to change significantly by 2030, based on today's policy settings alone*. <https://www.iea.org/news/the-energy-world-is-set-to-change-significantly-by-2030-based-on-today-s-policy-settings-alone>
- IEEE Spectrum. (2021). *Post-Fukushima Japanese microgrids*. <https://spectrum.ieee.org/postfukushima-japanese-companies-build-microgrids>
- Institute of Sustainable Futures. (2025). *Home*. <https://www.uts.edu.au/research/centres/isf>
- IPCC Report. (2021a). *IPCC Climate Change Report UN*. United Nations. <https://www.un.org/en/climatechange/what-is-climate-change>
- IPCC Report. (2021b). *IPCC Report Key Findings*. United Nations. <https://www.un.org/en/climatechange/science/key-findings>
- IRENA. (2023). <https://www.irena.org/>

- Jefferson, M. (2014). Closing the gap between energy research and modelling, the social sciences, and modern realities. *Energy Research & Social Science*, 4, 42–52. <https://doi.org/https://doi.org/10.1016/j.erss.2014.08.006>
- Kaczmariski, J. I. (2022). Public support for community microgrid services. *Energy Economics*, 115. <https://doi.org/10.1016/j.eneco.2022.106344>
- Khodayar, M. E. (2017). Rural electrification and expansion planning of off-grid microgrids. *Electricity Journal*, 30(4), 68–74. <https://doi.org/10.1016/j.tej.2017.04.004>
- Koirala, B. P., van Oost, E., & van der Windt, H. (2018). Community energy storage: A responsible innovation towards a sustainable energy system? *Applied Energy*, 231(June), 570–585. <https://doi.org/10.1016/j.apenergy.2018.09.163>
- Kola-Bezka, M. (2023). Think Global Act Local: In search for ways to increase the engagement of local communities in energy transition. *Energy Reports*, 9, 1668–1683. <https://doi.org/10.1016/j.egyr.2022.12.143>
- Komendantova, N., Riegler, M., & Neumueller, S. (2018). Of transitions and models: Community engagement, democracy, and empowerment in the Austrian energy transition. *Energy Research and Social Science*, 39(November 2017), 141–151. <https://doi.org/10.1016/j.erss.2017.10.031>
- Ilindala, M., Siddiqui, A., Venkataramanan, G., & Marnay, C. (2007). Localized aggregation of diverse energy sources for rural electrification using microgrids. *Journal of Energy Engineering*, 133(3), 121–131.
- Lu, X., Bahramirad, S., Wang, J., & Chen, C. (2015). *Microgrids : A Reliable , Resilient*. 28(10).
- Mariam, L., Basu, M., & Conlon, M. F. (2016). Microgrid: Architecture, policy and future trends. *Renewable and Sustainable Energy Reviews*, 64, 477–489. <https://doi.org/10.1016/j.rser.2016.06.037>

- Martin, M. (2010). Energy transitions in historical perspective. *The Energy Reader*, Wiley Blackwell, London, 45–60.
- McGookin, C., Ó Gallachóir, B., & Byrne, E. (2021). Participatory methods in energy system modelling and planning – A review. *Renewable and Sustainable Energy Reviews*, 151(July). <https://doi.org/10.1016/j.rser.2021.111504>
- Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*, 42, 323–340.
- Microgrid Knowledge. (2015). Community Microgrids: A Guide for Mayors and City Leaders Seeking Clean, Reliable and Locally Controlled Energy. *Energy Efficiency Markets LLC*, Richmond, VA, USA, Tech. Rep.
- Middelhoff, E., Andrade Furtado, L., Peterseim, J. H., Madden, B., Ximenes, F., & Florin, N. (2021). Hybrid concentrated solar biomass (HCSB) plant for electricity generation in Australia: Design and evaluation of techno-economic and environmental performance. *Energy Conversion and Management*, 240(February), 114244. <https://doi.org/10.1016/j.enconman.2021.114244>
- Miller, C. A., Iles, A., & Jones, C. F. (2013). The social dimensions of energy transitions. *Science as Culture*, 22(2), 135–148.
- Moloney, S., Horne, R. E., & Fien, J. (2010). Transitioning to low carbon communities-from behaviour change to systemic change: Lessons from Australia. *Energy Policy*, 38(12), 7614–7623. <https://doi.org/10.1016/j.enpol.2009.06.058>
- Monash University. (2025). *Monash Energy Institute*. <https://www.monash.edu/energy-institute>
- More Microgrids. (2009). Report on the technical, social, economic, and environmental benefits provided by Microgrids on power system operation. *WPG. Evaluation of the*

*System Performance on Power System Operation*, analysis of technical, social, economic and environ.

*National Centers for Environmental Information*. (2024). Billion Dollar Weather and Climate Disasters. <https://www.ncei.noaa.gov/access/billions/>,

Net Zero Plan. (2024). *Net Zero*.

New Vehicle Efficiency Standard. (2024). *New Vehicle Efficiency Standard*.

Olivares, D. E., Mehrizi-Sani, A., Etemadi, A. H., Cañizares, C. A., Iravani, R., Kazerani, M., Hajimiragha, A. H., Gomis-Bellmunt, O., Saeedifard, M., Palma-Behnke, R., Jiménez-Estévez, G. A., & Hatziargyriou, N. D. (2014). Trends in microgrid control. *IEEE Transactions on Smart Grid*, 5(4), 1905–1919. <https://doi.org/10.1109/TSG.2013.2295514>

Onu, U. G., Zambroni de Souza, A. C., & Bonatto, B. D. (2023). Drivers of microgrid projects in developed and developing economies. *Utilities Policy*, 80(December 2022), 101487. <https://doi.org/10.1016/j.jup.2022.101487>

Painuly, J. P. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, 24(1), 73–89.

Parag, Y., & Janda, K. B. (2014). More than filler: Middle actors and socio-technical change in the energy system from the “middle-out.” *Energy Research & Social Science*, 3, 102–112. <https://doi.org/https://doi.org/10.1016/j.erss.2014.07.011>

*Paris Accord Net Zero Emissions*. (2020).

Perez-DeLaMora, D. A., Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. G. (2021). Roadmap on community-based microgrids deployment: An extensive review. *Energy Reports*, 7, 2883–2898. <https://doi.org/10.1016/j.egyr.2021.05.013>

- Pidgeon, N., Demski, C., Butler, C., Parkhill, K., & Spence, A. (2014). Creating a national citizen engagement process for energy policy. *Proceedings of the National Academy of Sciences*, *111*(supplement\_4), 13606–13613.
- Planas, E., Andreu, J., Gárate, J. I., Martínez de Alegría, I., & Ibarra, E. (2015). AC and DC technology in microgrids: A review. *Renewable and Sustainable Energy Reviews*, *43*, 726–749. <https://doi.org/10.1016/j.rser.2014.11.067>
- Powering Australia. (2024). *Powering Australia*.
- Powering Past Coal Alliance. (2025). *Home*. <https://poweringpastcoal.org/>
- Prevedello, G., & Werth, A. (2021). The benefits of sharing in off-grid microgrids: A case study in the Philippines. *Applied Energy*, *303*(August), 117605. <https://doi.org/10.1016/j.apenergy.2021.117605>
- PSO. (2025, May). *Powering skills organization*. <https://poweringskills.com.au/>
- Pullins, S. (2019). Why microgrids are becoming an important part of the energy infrastructure. *Electricity Journal*, *32*(5), 17–21. <https://doi.org/10.1016/j.tej.2019.05.003>
- R. H. Lasseter. (2002). MicroGrids. *Proceeding of IEEE Power Engineering Society Winter Meeting*, *1*, 305–308.
- Radtke, J., & Scherhauser, P. (2022). A social science perspective on conflicts in the energy transition: An introduction to the special issue. *Utilities Policy*, *78*. <https://doi.org/10.1016/j.jup.2022.101396>
- S. Pati, K. B. Mohanty, A. Choudhury, & S. Kar. (2017). Integration and power control of a micro-hydro-PV-wind based hybrid microgrid. *2017 International Conference on Circuit ,Power and Computing Technologies (ICCPCT)*, 1–6. <https://doi.org/10.1109/ICCPCT.2017.8074183>.

- Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, 16(4), 584–603. <https://doi.org/10.1080/09644010701419121>
- Shahidehpour, M., & Clair, J. F. (2012). A Functional Microgrid for Enhancing Reliability, Sustainability, and Energy Efficiency. *Electricity Journal*, 25(8), 21–28. <https://doi.org/10.1016/j.tej.2012.09.015>
- Soeiro, S., & Ferreira Dias, M. (2020). Community renewable energy: Benefits and drivers. *Energy Reports*, 6, 134–140. <https://doi.org/10.1016/j.egyr.2020.11.087>
- Solar Energy Rebates. (2024). *Solar Energy Rebates and Incentives in Australia: A Comprehensive Guide*.
- Sovacool, B. K. (2009). Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. *Energy Policy*, 37(11), 4500–4513. <https://doi.org/https://doi.org/10.1016/j.enpol.2009.05.073>
- Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research and Social Science*, 1, 1–29. <https://doi.org/10.1016/j.erss.2014.02.003>
- Sovacool, B. K. (2016). How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy Research & Social Science*, 13, 202–215. <https://doi.org/https://doi.org/10.1016/j.erss.2015.12.020>
- Sovacool, B. K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: A synthesized approach. *Energy*, 36(8), 5343–5355. <https://doi.org/10.1016/j.energy.2011.06.043>
- State of the energy market. (2024). *State of the energy market 2024*.
- Statista. (2024). *Market size of microgrids worldwide*. <https://www.statista.com/statistics/1313998/global-microgrid-market-size/>

- Ternes, V., Marsden, G., & Harrison, G. (2024). A just transition or just a transition? The understanding and relevance of fairness in planning for a decarbonised transport system. *Energy Research and Social Science*, 113. <https://doi.org/10.1016/j.erss.2024.103549>
- The Australia Institute. (2021). *Local Power Agency Bill*. <https://australiainstitute.org.au/wp-content/uploads/2021/08/Australian-Local-Power-Agency-Bill-2021-submission-WEB.pdf>
- The Energy Efficiency Global Alliance. (2025). *Why energy efficiency*. <https://eeglobalalliance.org/>
- Thorpe, G. (2015). Assessment of edge of grid distributed generation alternative. *Oakley Greenwood*.
- Ton, D. T., & Smith, M. A. (2012). The U.S. Department of Energy's Microgrid Initiative. *Electricity Journal*, 25(8), 84–94. <https://doi.org/10.1016/j.tej.2012.09.013>
- Trombin, M., Pinna, R., Musso, M., Magnaghi, E., & De Marco, M. (2020). Mobility management: From traditional to people-centric approach in the smart city. *Emerging Technologies for Connected Internet of Vehicles and Intelligent Transportation System Networks: Emerging Technologies for Connected and Smart Vehicles*, 165–182.
- Ullman, A. N., & Kittner, N. (2024). Are global efforts coordinated for a Just Transition? A review of civil society, financial, government, and academic Just Transition frameworks. *Energy Research and Social Science*, 108. <https://doi.org/10.1016/j.erss.2023.103371>
- UN Sustainable Development Goals. (2025). *17 Goals to Transform Our World*. <https://www.un.org/sustainabledevelopment/>
- United Nations Climate Change. (2024). *Key aspects of the Paris Agreement*.
- United Nations Climate Change. (2025). *Conference of the Parties (COP)*. <https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop>

- University of Sydney. (2025). *Net Zero Institute*. <https://www.sydney.edu.au/net-zero-institute/>
- Ustun, T. S., Ozansoy, C., & Zayegh, A. (2011). Recent developments in microgrids and example cases around the world - A review. *Renewable and Sustainable Energy Reviews*, 15(8), 4030–4041. <https://doi.org/10.1016/j.rser.2011.07.033>
- van Summeren, L. F. M., Wieczorek, A. J., Bombaerts, G. J. T., & Verbong, G. P. J. (2020). Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands. *Energy Research and Social Science*, 63(May 2019), 101415. <https://doi.org/10.1016/j.erss.2019.101415>
- Victoria Energy Policy Centre. (2025). *Research and Insights*. <https://www.vepc.org.au/>
- Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy*, 36(2), 497–500. <https://doi.org/10.1016/j.enpol.2007.10.019>
- Wang, C., Yan, J., Marnay, C., Djilali, N., Dahlquist, E., Wu, J., & Jia, H. (2018). Distributed Energy and Microgrids (DEM). *Applied Energy*, 210, 685–689. <https://doi.org/10.1016/j.apenergy.2017.11.059>
- Wang, Y., Rousis, A. O., & Strbac, G. (2020). On microgrids and resilience: A comprehensive review on modeling and operational strategies. *Renewable and Sustainable Energy Reviews*, 134(September), 110313. <https://doi.org/10.1016/j.rser.2020.110313>
- Warneryd, M., Håkansson, M., & Karltorp, K. (2020). Unpacking the complexity of community microgrids: A review of institutions' roles for development of microgrids. *Renewable and Sustainable Energy Reviews*, 121(December 2019). <https://doi.org/10.1016/j.rser.2019.109690>
- Wei, P., & Chen, W. (2019). Microgrid in China: A review in the perspective of application. *Energy Procedia*, 158, 6601–6606. <https://doi.org/10.1016/j.egypro.2019.01.059>

Wu, R., & Sansavini, G. (2020). Integrating reliability and resilience to support the transition from passive distribution grids to islanding microgrids. *Applied Energy*, 272(March), 115254. <https://doi.org/10.1016/j.apenergy.2020.115254>

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683–2691. <https://doi.org/10.1016/j.enpol.2006.12.001>

# Chapter 2: Literature Review



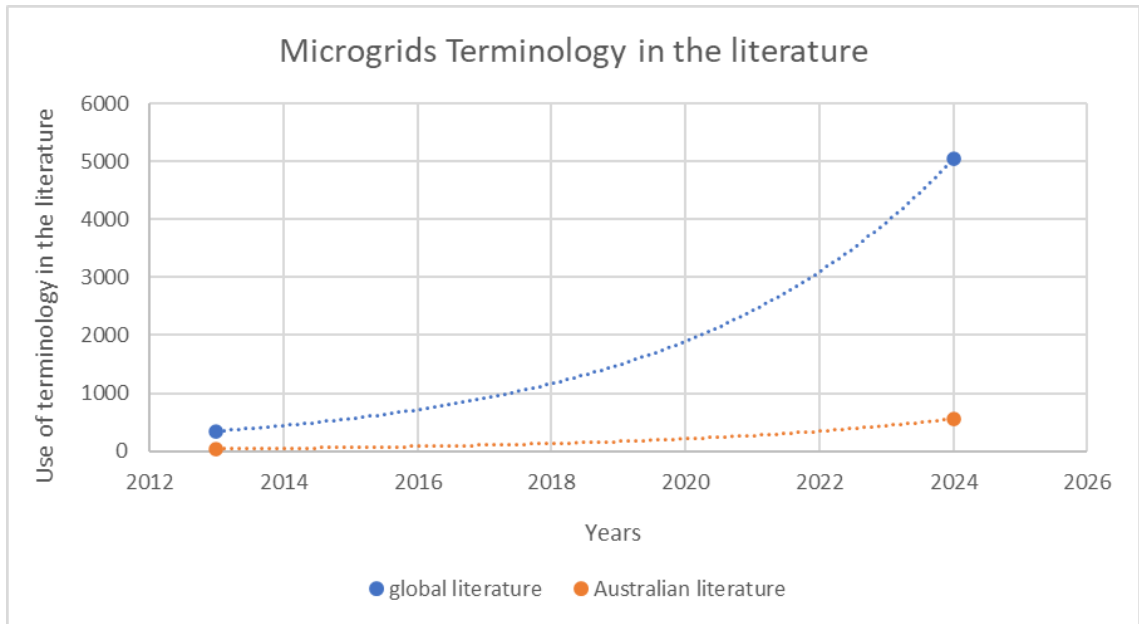
**Clairview & Stanage Bay community for the microgrid feasibility study.**

Retrieved from <https://www.ergon.com.au/network/our-services/projects-and-maintenance/major-projects/greater-queensland-projects/clairview-and-stanage-bay-microgrid-feasibility-study>

## Chapter 2. Literature Review

This chapter synthesises the current scholarship on microgrids, exploring the central debates and challenges related to community engagement in microgrids. While the technical aspects of microgrids are crucial and have extensively received scholarly attention, the social dimensions are equally important for their successful implementation. Social science research has explored a range of themes relevant to microgrid implementation and the energy transition, including public participation, social acceptance, social cohesion, and community engagement. Despite extensive research on the social aspects of renewable energy projects, a significant gap exists in the literature concerning the social dimensions of microgrids.

The term "microgrid" has gained significant traction in both academic and non-academic literature over the past decade. A keyword search for "microgrids" in the Elsevier ScienceDirect database reveals a substantial increase in its usage. In 2013, the term appeared 344 times, whereas by 2024, this number had risen to 5,047, indicating a growing interest in the topic (see Figure 3). When combined with the keyword "Australia," the search results similarly increased from 39 in 2013 to 558 in 2024 (see Figure 3). This trend indicates the increasing prominence of microgrids as a potential solution to electrification challenges.



*Figure 3 Microgrid Terminology in the Literature*

To better understand the extent of existing literature on the social aspects of microgrids, a keyword index approach was employed to assess the volume of relevant academic research. The search was conducted in December 2024, utilising the Science Direct database. This process revealed a notable disparity in the volume of research being conducted between the techno-economic aspects of microgrids and those related to community engagement and social aspects. Various combinations of search terms, such as "microgrids AND technical" and "microgrids AND control," yielded a significant number of articles (n=17,091 and n=18,802), respectively. However, the combination of keywords such as "microgrids AND social" (n=5623) and "microgrids AND community engagement" (n=176) resulted in a considerably smaller number of results. The details of the results using the keyword analysis index are shown in Figure 4:

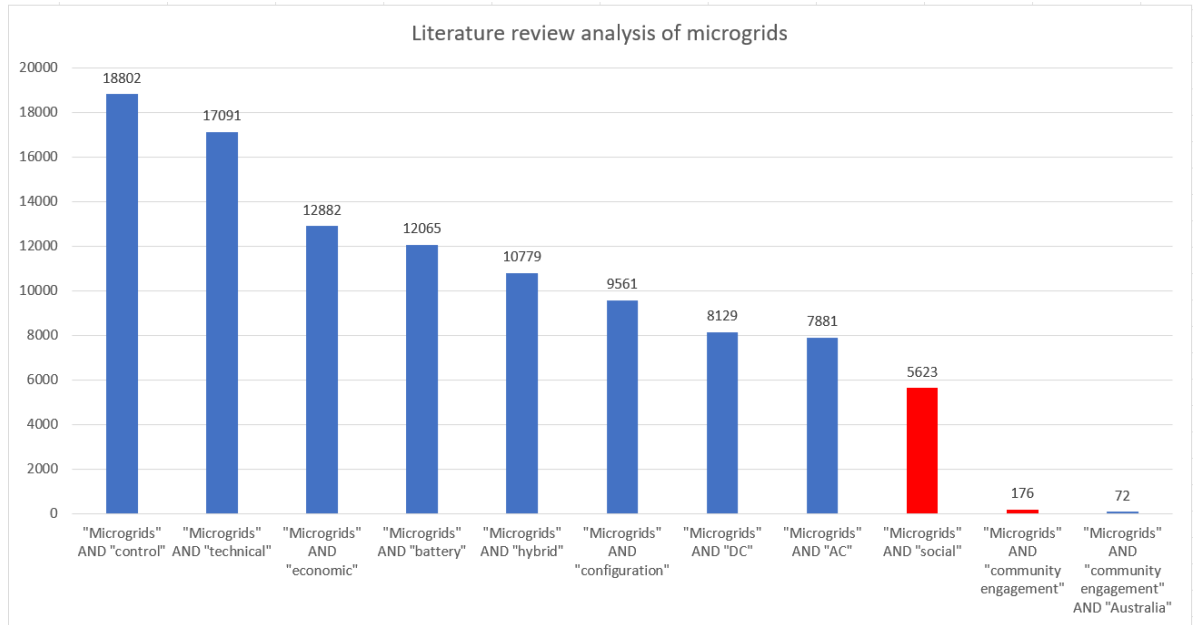


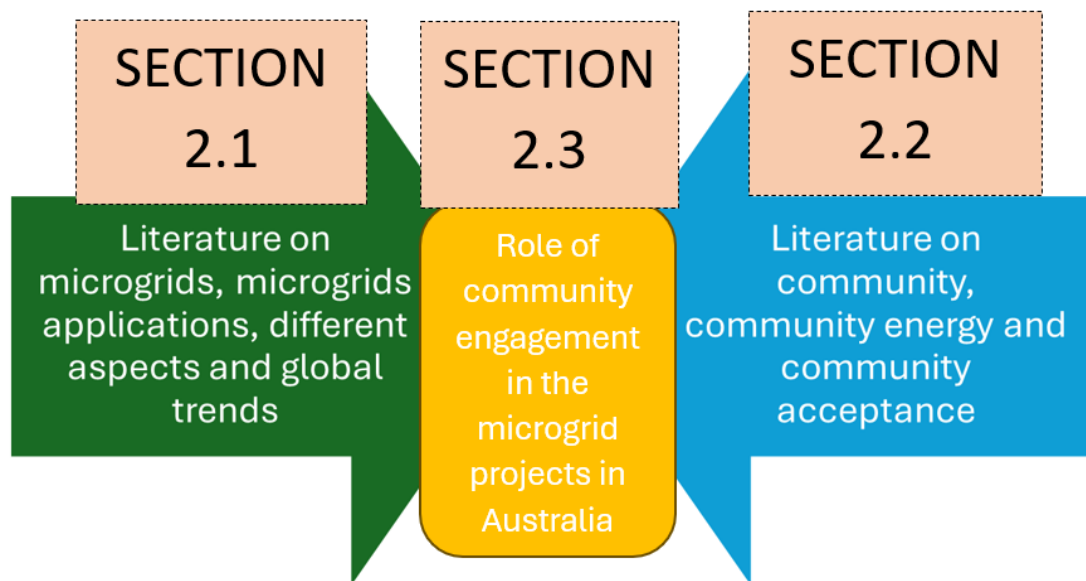
Figure 4 Literature Review Analysis of Microgrids

To complement the ScienceDirect search, a similar keyword analysis was conducted using Google Scholar in August 2025. The results highlighted a broader coverage of publications compared to ScienceDirect, reflecting Google Scholar's inclusion of conference proceedings, theses, and grey literature in addition to peer-reviewed journal articles. The keyword combination *"microgrids AND technical"* returned approximately 26,000 results, while *"microgrids AND control"* produced around 40,500 results. In contrast, searches focusing on social dimensions produced fewer results: *"microgrids AND social"* yielded 17,600, and *"microgrids AND community engagement"* returned 15,300 publications. Narrowing the focus to the Australian context reduced the count further, with *"microgrids AND community engagement AND Australia"* yielding 6,350 results. These findings reaffirm the disparity between the abundance of research on techno-economic aspects of microgrids and the relatively smaller, though growing, body of work addressing social and community-related dimensions. This trend is in alignment with Figure 4, which depicts a significant gap in the literature regarding the social aspects of microgrids, particularly community engagement. Despite the recognised advantages

of community involvement in microgrid implementation, this area remains under-explored (Eklund et al., 2023; Muttaqee et al., 2023). This thesis explores the integral role of communities in microgrid development, arguing that community engagement and social factors are inextricably linked to the long-term success and sustainability of these projects. This literature review chapter has been divided into two main sections. Section 2.1 of the literature review focuses on the microgrids literature. This section is subdivided into sections based on microgrid definitions, applications, and potential benefits. It concludes with an exploration of the technical, economic, and social aspects of microgrids. The section will also identify the definition of a 'microgrid' selected for this thesis, along with the rationale behind it.

The second section of this chapter (section 2.2) explores the literature on community energy projects with a focus on microgrids. This section is subdivided into a section that defines the term "community", with subsequent sections on community energy projects, community acceptance of renewable energy technologies, and the exploration of the literature on community engagement in microgrid projects. Since the term "community microgrids" is used in the literature, section 2.2.6 is dedicated to community microgrids, the rationale behind deploying microgrids, and different interpretations of community microgrids, concluding with a discussion on the terminology used to describe "community microgrids". Section 2.3 identifies existing gaps in the literature uncovered during the review of the literature. A link between the research questions and the research gaps will also be established in section 2.3.

While a substantial portion of the reviewed literature was accessed via the Elsevier database, additional sources were consulted to ensure a comprehensive overview of the field. Figure 5 shows the structure of the literature review being undertaken in this thesis, highlighting the critical aspects which will be reviewed in this chapter.



*Figure 5 Contextualising the Literature Review*

## 2.1 Understanding microgrids: Definitions and existing research

### 2.1.1 Microgrids – definition, advantages and applications

This section provides an overview of microgrids, encompassing their definitions, applications, and key advantages. The concept of microgrids was first formalised in the 1990s by Lasseter and colleagues, primarily as a means of coordinating distributed energy resources (DERs). While not limited to renewable energy sources, the concept has since become closely associated with facilitating renewable integration into conventional grids (Hirsch et al., 2018; Lu et al., 2015; R. H. Lasseter, 2002). Systematic research and development programs in microgrids began with initiatives such as the Consortium for Electric Reliability Technology Solutions (CERTS) in the United States (Hatziargyriou, 2013; Lasseter, R. et al., 2002). CERTS, established in 1999, is widely recognised as the foundation of the modern grid-connected microgrid concept. It envisioned a microgrid as a technology possessing the capability of integrating multiple distributed energy resources (DERs) while appearing to the main grid as a single entity or small generator (Marnay & Giri Venkataramanan, 2006).

Microgrids can enhance the reliability and resilience of the electricity supply by utilising Distributed Energy Resources (DERs) (Onu et al., 2023). Specifically, the ability to supply uninterrupted electricity to critical loads in the event of a major power outage or emergency has resulted in a significant willingness to pay for this technology among consumers (Hotaling et al., 2021; Kabalci, 2018). Besides providing a resilient and reliable supply of electricity, microgrids also play a vital role in reducing CO2 emissions and fuel costs by utilising renewable energy sources instead of conventional fossil-fuelled energy (Shahbazitabar et al., 2021). While microgrids are often found to reduce emissions, emissions reductions are not a prerequisite for a microgrid. Indeed, some microgrids that run predominantly on diesel generators may increase emissions when compared to taking electricity from the grid. Figure 6 represents the simple microgrid structure adopted from (Shahbazitabar et al., 2021).

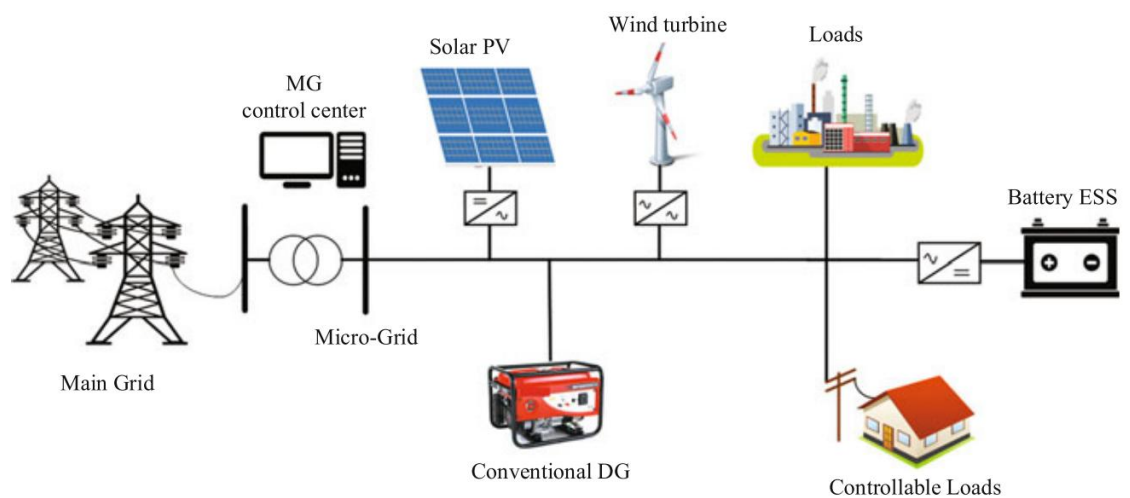


Figure 6 Simple microgrid structure

#### 2.1.1.1 Global trends in microgrids deployment

The interest in microgrids has increased in the last decade, with the increasing uptake of renewable energy systems and reduction in the capital costs of renewable energy technologies and energy storage systems (Hirsch et al., 2018; Khodayar, 2017). Currently, microgrids are emerging as a promising solution for local power generation,

driven by technological advancements (Vanadzina et al., 2019) and reduced cost of small-scale distributed technologies such as solar PV, battery storage, micro hydropower, and small-scale wind power (Darghouth et al., 2020). The global microgrid market is projected to grow from USD 37.6 billion in 2024 to USD 87.8 billion by 2029 at a CAGR of 18.5% (Markets and Markets, 2024). Asia-Pacific is identified as the fastest-growing region, driven by China's and India's focus on renewable-based distributed energy, with the market expected to reach USD 34.3 billion by 2029 and a CAGR of 22.4% during the forecast period. North America also remains a significant market, driven by the need for resilience (Horizon Grand View Research, 2024c). Overall, the global microgrid market is anticipated to triple in value from 2020 to 2030 (Bloomberg NEF, 2024; Horizon Grand View Research, 2024c; Markets and Markets, 2024; Microgrid Knowledge, 2024a).

The U.S. microgrid market is among the most mature globally, driven by the need for resilience against extreme weather events such as hurricanes and wildfires (Muttaqee et al., 2023). Since the early 1990s, the U.S. microgrid industry has grown significantly, increasing from fewer than 30 sites with a combined capacity of 570 MW to nearly 700 microgrids capable of generating approximately 4.4 GW of electricity (Microgrid Knowledge, 2024a), with projections indicating nearly double that capacity by 2030 (Wood Mackenzie, 2024). States like California, New York, and Massachusetts have played a pivotal role in advancing microgrid adoption by introducing or expanding incentive programs for microgrids and energy storage systems (Ajaz & Bernell, 2021). The Bipartisan Infrastructure Act, passed by the US House of Representatives, includes a \$1 trillion legislative package with \$65 billion dedicated to overall grid improvements, of which \$3.45 billion will fund approximately 400 microgrid projects nationwide (Microgrid Knowledge, 2024b).

China has emerged as a global leader in microgrid deployment, driven by its commitment to renewable energy integration and grid modernisation (Wei & Chen, 2019). According

to the International Renewable Energy Agency (IRENA), China has made significant strides in implementing microgrids, particularly in industrial and remote regions (Renewable Energy Agency, 2022). The China microgrid market generated a revenue of USD 7,029.2 million in 2023 and is projected to reach USD 24,274.0 million by 2030, growing at a CAGR of 19.4% from 2024 to 2030 (Horizon Grand View Research, 2024b). The country's 13th Five-Year Plan (2016–2020) laid the groundwork for microgrid pilot projects, and the 14th Five-Year Plan (2021–2025) builds on this progress by prioritising distributed generation and enhancing grid resilience (Yu et al., 2018). The Chinese government has allocated substantial funding, including billions of RMB in grants and incentives for distributed energy resource (DER) projects, as part of its strategy to achieve carbon neutrality by 2060 (Renewable Energy Agency, 2022). Besides, Japan's focus on disaster resilience, particularly following the 2011 earthquake and tsunami, has significantly advanced the adoption of microgrids to enhance energy security (IEEE Spectrum, 2021). Many companies are implementing on-site microgrids to mitigate power outages and incorporate renewable energy sources. According to a Bloomberg report, Japan's microgrid market is projected to grow at a compound annual growth rate (CAGR) of 10–12% through 2030, fueled by increased corporate investment and supportive government policies (Bloomberg NEF, 2024).

Similarly, Europe's microgrid market is poised for significant growth despite holding a smaller share of global capacity than other regions. Europe accounted for less than 10% of the world's microgrid power capacity, compared to 33% in the U.S (Rod Walton, 2024). In 2022, the European grid-connected microgrid market was valued at approximately USD 3.8 billion. Although Europe's market is currently just over one-fifth the size of the U.S. market, valued at nearly USD 17 billion, it is projected to grow at an annual rate of 15.9% and exceed USD 16 billion by 2032 (Rod Walton, 2024). The Canadian microgrid market is also experiencing significant growth, generating USD 3.4 billion in revenue in 2023 and projected to reach USD 9.3 billion by 2030, with a CAGR of 15.5% from 2024

to 2030 (Horizon Grand View Research, 2024a). Canada is actively transitioning northern and remote Indigenous communities from diesel generators to clean energy microgrids, promoting sustainability and energy independence. Urban regions, such as Ontario and Alberta, are also witnessing increased microgrid adoption in commercial and industrial sectors, including factories, campuses, and data centres, driven by the need for greater energy resilience (Government of Canada, 2024). Federal initiatives like Natural Resources Canada's Smart Grid Program further support microgrid development by offering grants and rebates for feasibility studies and deployments, particularly those integrating renewable energy and battery storage solutions (Government of Canada, 2024).

#### 2.1.1.2 Microgrids applications

Microgrids are increasingly deployed across a range of critical locations such as data centres, electric vehicle (EV) charging stations, healthcare facilities, manufacturing sites, commercial buildings, university campuses, and military bases to ensure reliable, localised power (Microgrid Knowledge, 2024b). The scale of microgrids exhibits significant variability, spanning from small-scale systems designed for a limited number of households (e.g., ten) to large-scale deployments capable of serving communities with populations of hundreds of thousands (Gui et al., 2017). The adaptability of microgrids to managing diverse critical and non-critical loads makes them suitable for numerous applications, spanning from schools and mining operations to airports, regional communities, government facilities, commercial and industrial precincts, remote islands, residential areas, and agricultural sites (B. Richter et al., 2019; Guerrero M. Josep & Kandari Ritu, 2021; Hadjidemetriou et al., 2018; Lu et al., 2015; Rezkallah et al., 2019; Shah Danish et al., 2019; Shahidehpour & Clair, 2012; Vanadzina et al., 2019). Microgrids are thus emerging as essential elements of modern energy systems, providing communities of varying sizes with enhanced resilience, flexibility, and sustainable power solutions.

### *2.1.1.3 System configuration*

The microgrid's system configuration enables operation in three distinct modes, including a DC configuration (Kabalci, 2018; M. Lonkar & S. Ponnaluri, 2015; Planas et al., 2015; Ullah et al., 2020), AC configuration (A. Alfergani et al., 2018; A. Mohammed et al., 2019; Kabalci, 2018; Meje et al., 2020; Planas et al., 2015; S. M. Kaviri et al., 2017) and hybrid mode (F. Nejabatkhah & Y. W. Li, 2015; Guerrero M. Josep & Kandari Ritu, 2021; Kabalci, 2018; Lu et al., 2016; S. Pati et al., 2017; Unamuno & Barrena, 2015) allowing flexibility in its operation. Limouni et al. (2025) in their research provided the architecture of these three microgrid configurations presented in Figure 7 (Limouni et al., 2025).

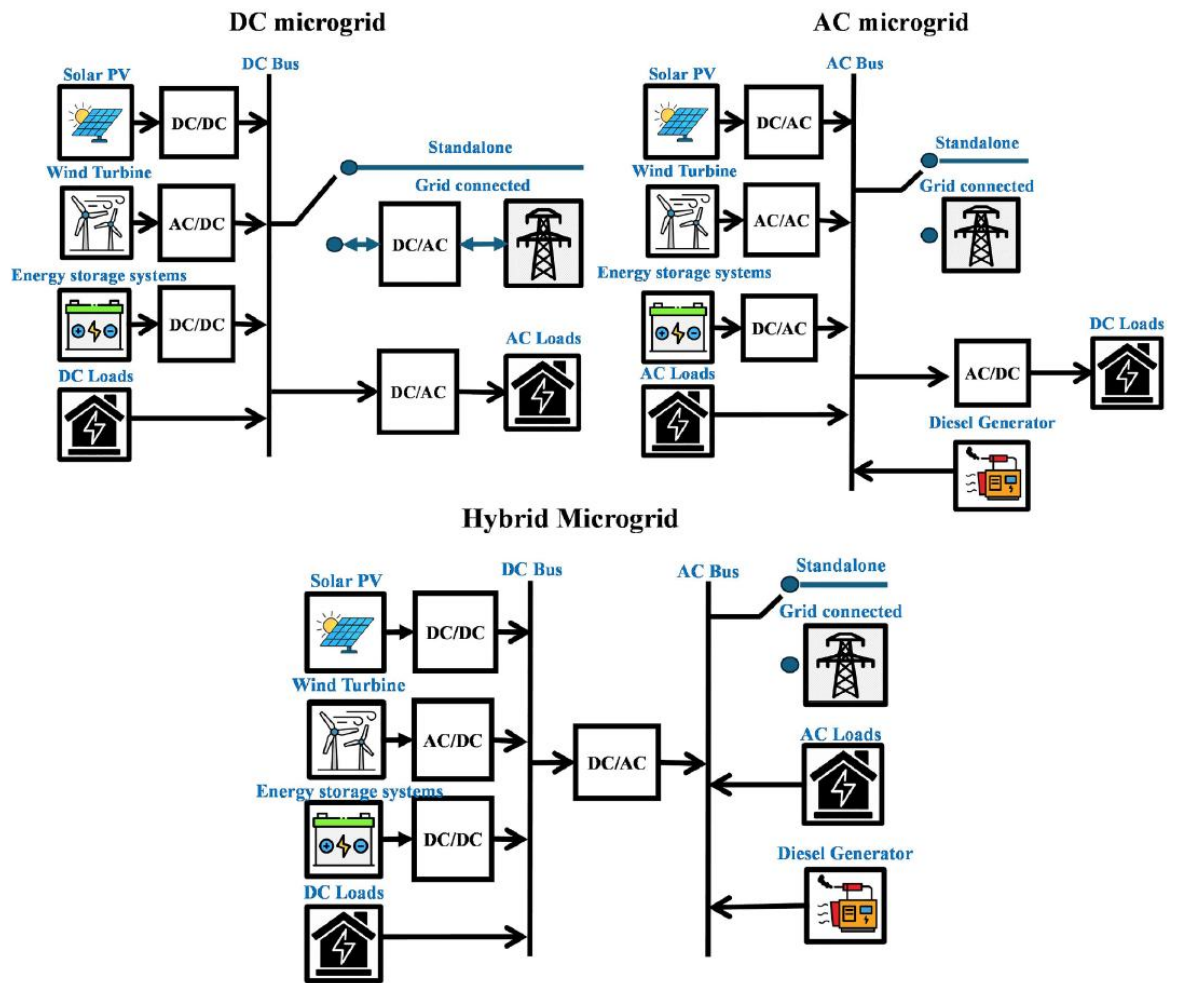


Figure 7 Microgrid architecture for three configurations

#### 2.1.1.4 Distinguishing Microgrids, Virtual Power Plants and Minigrids

Microgrids, Virtual Power Plants (VPPs), and minigrids are often conflated in both academic and industry discussions, yet they represent distinct concepts within decentralised energy systems.

Microgrids are localised energy systems designed to balance generation and demand within a defined geographic boundary. They commonly integrate renewable energy, storage, and hardware-based control mechanisms (e.g., inverters, smart switches) to maintain stability and reliability (More Microgrids, 2009). A defining characteristic of microgrids is their ability to operate in both grid-connected and islanded modes, ensuring continuity of supply during wider grid outages (Asmus, 2010). VPPs, in contrast, are software-driven systems that aggregate distributed energy resources (DERs) across

much larger geographic areas. They rely on digital platforms, smart meters, and automation to optimise the dispatch of diverse resources in real time. Unlike microgrids, which manage a relatively fixed set of assets within a physical boundary, VPPs are designed to act as “virtual generators” capable of participating in wholesale energy markets and providing system-level services across the grid (Asmus, 2010).

Similarly, the terms microgrid and minigrid are sometimes used interchangeably, though they describe different systems (Perez-DeLaMora et al., 2021). Both involve decentralised electricity provision, but microgrids are usually embedded within or alongside larger grid systems and have the capability to switch between grid-connected and islanded operation. Minigrids, on the other hand, generally refer to stand-alone, off-grid networks designed to serve rural or remote communities where central grid extension is not viable (Andy Haun, 2018). These systems tend to be simpler in design, often operating at lower voltages with less sophisticated control mechanisms, and focus on providing basic, reliable, and affordable electricity access (Ruchi Soni, 2020). While both may utilise renewable energy technologies, microgrids are associated with more advanced control, higher integration of DERs, and seamless interaction with central grids, whereas minigrids are typically deployed as cost-effective rural electrification strategies.

Clarifying these distinctions is important, as the confusion between microgrids, minigrids, and VPPs is frequently observed in both academic literature and grey reports, despite their significant differences in scope, operation, and application.

### 2.1.2 Microgrids Definitions

The term "microgrid" does not have a universally standardised definition and is subject to various interpretations depending on the context (Basak et al., 2012; Feng et al., 2018; Soshinskaya et al., 2014). Different applications and configurations have also made defining what a microgrid is more challenging (Guibentif & Vuille, 2022). Some

researchers, such as Lasseter (2002), have viewed a microgrid as "a system approach that considers generation and associated loads as a subsystem" (R. H. Lasseter, 2002). Tao et al. (2011) offered a more specific definition, describing it as "an integration platform for supply-side (micro-generators) and demand-side resources (storage units and controllable loads) within a local distribution grid" (Tao et al., 2011). These varying perceptions have ascribed the complexity and evolving nature of the technology. This section explores the various definitions used in the literature.

The concept of microgrids was first introduced by the USA's Consortium for Electric Reliability Technology Solutions (CERTS) as they defined microgrids as "*a group of interconnected loads and distributed resources operating as a single unit to provide heat and power to the community*" (Lasseter & Paigi, 2004; Madureira, 2010; Planas et al., 2015; Shahbazitabar et al., 2021). This simplistic definition was one of the earliest definitions of microgrids, where the intention was to introduce the grid to provide electricity and heat to the local community using Distributed Energy Resources (DERs). However, the literature review has uncovered that the most cited definition of microgrid is proposed by the Department of Energy (DOE) in the US, defining microgrids as:

*"a microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode"* (Ajaz & Bernell, 2021; Guibentif & Vuille, 2022; Hirsch et al., 2018; Hotaling et al., 2021; Pullins, 2019; Vanadzina et al., 2019; C. Wang et al., 2018; Warneryd et al., 2020). Most researchers have adopted this definition or its variations, as it encompasses key aspects of the microgrid concept. This definition addresses critical components of microgrids, such as the microgrid's boundary, the integration of distributed energy resources (DERs), islanding capability, and its operation as a single controllable entity, making it a widely accepted definition among researchers. Lu et al. (2016) have defined microgrids as "*a discrete energy system composed of*

*DERs (e.g., renewables and storage and loads), possessing the capability of operating in parallel with or independently from the main grid*" (Lu et al., 2016). This definition was the basic version of what has been defined in the DOE definition, as it doesn't mention the operation in the boundary or acting as a single entity. The definition has, however, hinted towards the islanded operation of the microgrid.

Khodayar (2017) has defined microgrids in a similar way as proposed by DOE, stating, *"a microgrid refers to a collection of distributed generation units and demand entities that are interconnected within a defined boundary, presenting itself as a single, manageable unit within the utility grid. It can function in either grid-connected or island mode"* (Khodayar, 2017). This definition is also derived from the DOE definition, uncovering the same aspects as proposed by DOE but defined in a simple language. Soshinskaya et al. (2014) have defined the concept of microgrids in a relatively simpler manner, defining microgrids as *"small-scale energy systems that combine renewable and conventional energy sources with storage, linked through energy management systems in smart buildings. This setup allows local consumers to meet some or all of their energy needs through self-generated power while still being connected to the central grid"* (Soshinskaya et al., 2014). The authors employ the term "smart building" because their research focuses on that specific context. However, microgrids are also a viable solution not only for consumers in smart buildings but also for rural and remote communities. This observation corroborates the point made in the literature review (Section 2.1), which indicates that microgrids are generally defined in relation to how they are deployed in various applications.

Another study conducted by Asmus (2010) defines a *microgrid as "an integrated energy system comprising distributed energy resources and multiple electrical loads, operating either in parallel with or independent from the central power grid"* (Asmus, 2010). This definition has not considered the operational boundaries of microgrids, whether they are functioning within a limited area or covering a larger geographical region. In their

research, Shahbazitabar et al. (2021) have defined microgrids as “*electricity distribution systems containing loads and distributed energy resources (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way, either while connected to the main power network or while islanded*” (Hatziaargyriou, 2013; Shahbazitabar et al., 2021). This microgrid definition did not mention the boundary in which the microgrids operate. While defining a modern microgrid, Wouters (2015), in his research, identified three key factors that are important for microgrid characterisation. (1) the presence of small-scale generation units, energy loads, and possible storage systems, (2) the ability to interconnect with the main grid, either in grid-connected or island mode, and (3) its implementation at the low-voltage distribution level (NYSERDA, 2021; Romankiewicz et al., 2014; Wouters, 2015).

Su & Wang, (2012) has defined the modern microgrid “*as a power distribution network made up of multiple loads and distributed energy resources. These systems can operate either independently or alongside the central grid, coordinating the operation of all DERs, including loads and storage, in a controlled manner to optimise performance and achieve operational cost savings, all while maintaining real-time interaction with the main grid*” (Su & Wang, 2012). Unlike the previously mentioned definitions, this definition introduced the concept of optimisation. However, most of the other aspects remain consistent with the DOE definition. Gui et al. (2017) have stated a more application-focused definition and defined microgrids as: “*a self-contained local electricity system that may function either independently or in connection with a centralised grid. It supports various loads—residential and others—and is often backed by high levels of distributed renewable energy sources*” (Gui et al., 2017).

The reviewed definitions highlight the complexity of microgrids, with varying interpretations tailored to specific use cases. A common thread in the literature is the emphasis on connectivity to the main grid, which is consistently highlighted as critical to enhancing reliability and resilience. Besides, the islanding capability of microgrids (the

ability to operate independently during main grid outages) highlights their critical role in ensuring autonomous and resilient electricity supply. Most definitions of microgrids emphasise the use of distributed energy resources (DERs), such as solar, wind, or biomass, indicating a general preference for their operation with renewable energy sources. While diesel-powered microgrids are also commonly utilised in rural and remote communities (Anderson et al., 2022; Daniel Schnitzer, Deepa Shinde Lounsbury, Juan Pablo Carvallo et al., 2014; Jiayi et al., 2008; Kirubi et al., 2009), this thesis specifically focuses on microgrids powered by renewable energy resources. For the purposes of this thesis, the term "microgrids" refers specifically to microgrids incorporating renewable energy generation, though acknowledging that the term can also encompass systems with non-renewable generation. This thesis adopts the definition of microgrids proposed by the U.S. Department of Energy (DOE), as it encompasses various aspects such as operation within a defined boundary, islanding capability, use of distributed energy resources (DERs), and functioning as a single entity.

### 2.1.3 Review of Key Aspects of Microgrids in Existing Literature

Existing literature explores various dimensions of microgrids, including technical intricacies, economic aspects, and the policy frameworks governing their implementation. These studies emphasise the adaptability of microgrids in addressing challenges related to energy generation, distribution, and consumption. This section examines key themes within the microgrid literature, encompassing technical, economic, regulatory, business model, and policy considerations.

#### 2.1.3.1 Microgrids and economic aspects – business models

A critical evaluation of the literature reveals both complementary and divergent perspectives on the viability of microgrid business models. While Sousa et al. (2019) and Zia et al. (2020) advocate for decentralised, peer-to-peer (P2P) market structures to empower prosumers, their reliance on theoretical frameworks and simulations, while

valuable for exploring potential market mechanisms (Sousa T. et al., 2019; Zia M.F. et al., 2020), does not fully address the complexities of real-world implementation. Specifically, these approaches may not fully capture the influence of regulatory constraints, tariff structures, and the heterogeneity of consumer behaviour. In contrast, Vanadzina et al. (2019) and Guibentif & Vuille (2022) emphasise the importance of context-specific business model classifications, recognising the influence of system scale, ownership structures, and local energy prices on project feasibility (Guibentif & Vuille, 2022; Vanadzina et al., 2019). Although their typologies offer valuable frameworks, they could benefit from a more nuanced exploration of the dynamic interplay between community engagement and economic rationale. While Vanadzina et al. (2019) provide a valuable categorisation of ownership and revenue strategies, their analysis insufficiently addresses the potential for social or political resistance to impede implementation (Vanadzina et al., 2019). Guibentif & Vuille (2022), in their study of the Swiss context, effectively demonstrate the crucial role of regional policies. However, their case study approach, while providing in-depth analysis, limits the broader applicability of their findings (Guibentif & Vuille, 2022).

The economic dimensions of microgrid deployment are explored by Stadler et al. (2016) and Hanna et al. (2017). While Stadler et al. (2016) thoroughly document the technical and financial challenges, their analysis would benefit from explicitly situating these challenges within the broader socio-political landscape that shapes investment decisions (Stadler et al., 2016). Hanna et al. (2017) contribute a valuable cost-minimisation tool (DER-CAM), offering a holistic perspective on capacity planning and operational optimisation (Hanna et al., 2017). However, the inherent reliance of these models on input assumptions necessitates careful consideration of their limitations, especially concerning the potential impact of fluctuating fuel prices, evolving policy incentives, and advancements in storage technologies on long-term projection accuracy.

Martin-Martinez et al. (2016) and Asmus (2010) offer future-oriented perspectives, examining potential market transformations driven by emerging technologies such as Virtual Power Plants. While Martin-Martinez et al. (2016) provide a global overview, their analysis involved a deeper consideration of local contextual factors, including cultural acceptance, regulatory heterogeneity, and variations in grid infrastructure (Martin-Martínez et al., 2016). Similarly, Asmus (2010), while differentiating between microgrids and VPPs, has thoroughly explored the practical challenges of integrating these systems into existing grid infrastructure, notably addressing interoperability standards and cybersecurity vulnerabilities (Asmus, 2010).

Reflecting on the evolving landscape of the microgrid sector, recent research, such as that by Eklund et al. (2024) and Wright et al. (2024), has increasingly prioritised the study of viable business models. Eklund et al. (2024) employ Multi-Criteria Decision Analysis (MCDA) to facilitate stakeholder evaluation of business models, acknowledging the multifaceted nature of microgrid projects (Eklund et al., 2024). However, the inherent subjectivity in MCDA weightings warrants careful consideration of potential biases arising from misaligned stakeholder priorities. Additionally, Wright et al. (2024), focusing on Australian microgrid projects, provide valuable insights into context-specific drivers and barriers, but the transferability of their findings to regions with different policy landscapes requires careful assessment (Wright et al., 2024). Prevedello & Werth (2021), using agent-based modelling in off-grid contexts, demonstrate the potential for cost reductions through asset sharing, highlighting the importance of collective action in resource-constrained environments (Prevedello & Werth, 2021).

The literature demonstrates the promise of diverse microgrid business models, including P2P trading and community ownership, but also identifies methodological, contextual, and scalability limitations, requiring further research.

### 2.1.3.2 Technical challenges and innovations in microgrids

The literature on microgrid architectural design and control systems highlights a disparity between the rapid pace of technical advancements and the persistent challenges to widespread deployment. Lu et al. (2015, 2016), for instance, demonstrate the technical feasibility of integrating microgrids with existing Distribution Management Systems (DMS), exemplified by projects like the Bronzeville microgrid project (Lu et al., 2015, 2016). The layout of the control architecture has been presented in Figure 8.

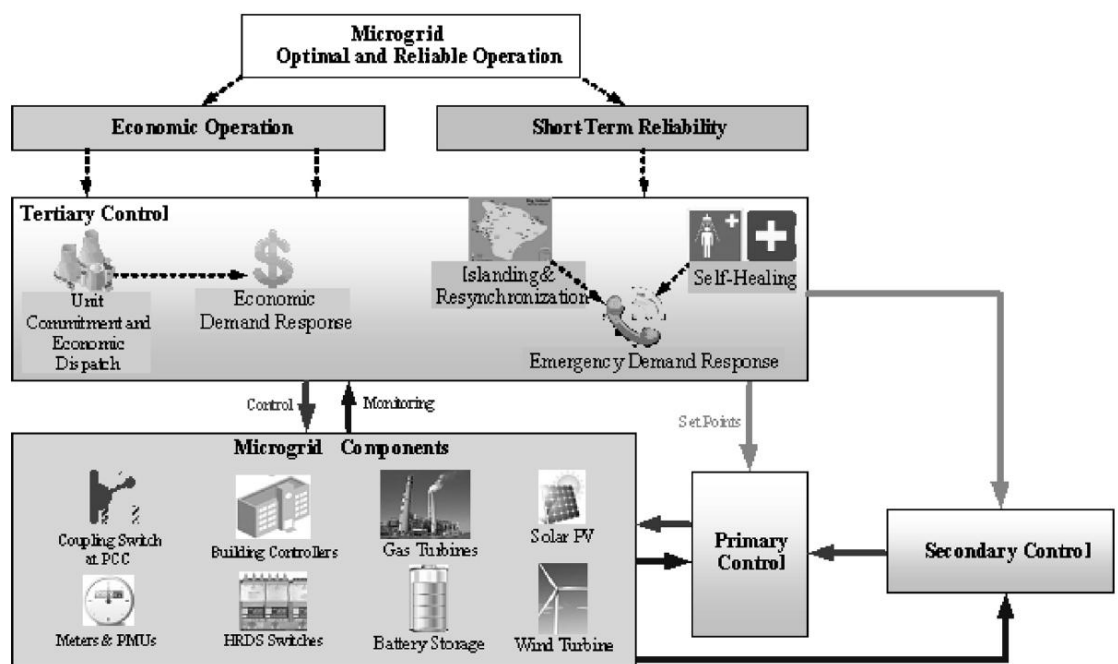


Figure 8 Layout of control architecture

However, the reliance on context-specific conditions (e.g., existing infrastructure, regulatory support) raises concerns about the scalability of their approach in regions with differing resource availability. Furthermore, while Wang et al. (2018) and Shahbazitabar et al. (2021) offer valuable contributions to microgrid structure and control scheme planning, optimisation, and categorisation (Shahbazitabar et al., 2021; C. Wang et al., 2018), their predominantly technical focus overlooks the significant role of social and economic factors, such as community acceptance and cost constraints, in shaping real-world deployment.

Several studies effectively advocate for advanced microgrid architectures, including hybrid AC/DC and converter-based systems, to enhance operational flexibility (Hossain et al., 2019; Unamuno & Barrena, 2015). These studies contribute valuable theoretical frameworks and prototype demonstrations, laying the groundwork for exploring the potential of these advanced designs. However, a key limitation lies in the relative scarcity of empirical evidence validating the long-term reliability and cost-effectiveness of these architectures when deployed at scale. Similarly, Hirsch et al. (2018) and Meje et al. (2020) offer valuable multi-perspective reviews, integrating technical, policy, and social dimensions of microgrid development. Their holistic approach is a significant strength, recognising the interconnectedness of these factors in successful microgrid implementation (Hirsch et al., 2018; Meje et al., 2020). However, while acknowledging the complexities of stakeholder coordination, their analyses could further explore the practical challenges of navigating these complexities in diverse community settings.

Similarly, Zhou et al. (2018) and Y. Wang et al. (2020) emphasise resilience-oriented planning and the role of microgrids in mitigating disruptions, primarily utilising modelling approaches (Y. Wang et al., 2020; Zhou et al., 2018). These modelling approaches are a key strength, allowing them to simulate various disruption scenarios and assess the effectiveness of different microgrid configurations in enhancing grid resilience. However, while these models offer valuable insights into resilience planning, they do not fully capture the dynamic influence of evolving regulatory landscapes and the complexities of ensuring financial viability for microgrids operating within diverse grid contexts.

The study of stability and control in islanded microgrids emphasises the need for rigorous mathematical frameworks for frequency regulation and stability evaluation (Heidari et al., 2017). Syed & Morrison (2021) adopted a rapid review methodology for assessing the role of microgrids in multi-residential settings, outlining microgrid configurations for the implementation. However, their approach insufficiently addresses the critical alignment of proposed solutions with actual occupant needs and broader energy sustainability

goals (Syed & Morrison, 2021). The role of monitoring, protection, and control schemes in effective microgrid operation is recognised by Cagnano et al. (2020) and Planas et al. (2013) in their research (Cagnano et al., 2020; Planas et al., 2013). However, these studies have the potential to further investigate the interplay between technical mechanisms and non-technical factors, such as regulatory frameworks and grid market structures, which significantly influence the feasibility of widespread adoption. Yamashita et al. (2020) and Salehi et al. (2022) provide valuable comparative analyses of hierarchical and optimisation-based control strategies, laying a strong foundation for understanding their relative strengths and weaknesses. Figure 9 presents the hierarchical control structure including three control layers (Abdellatif Elmouatamid et al., 2020).

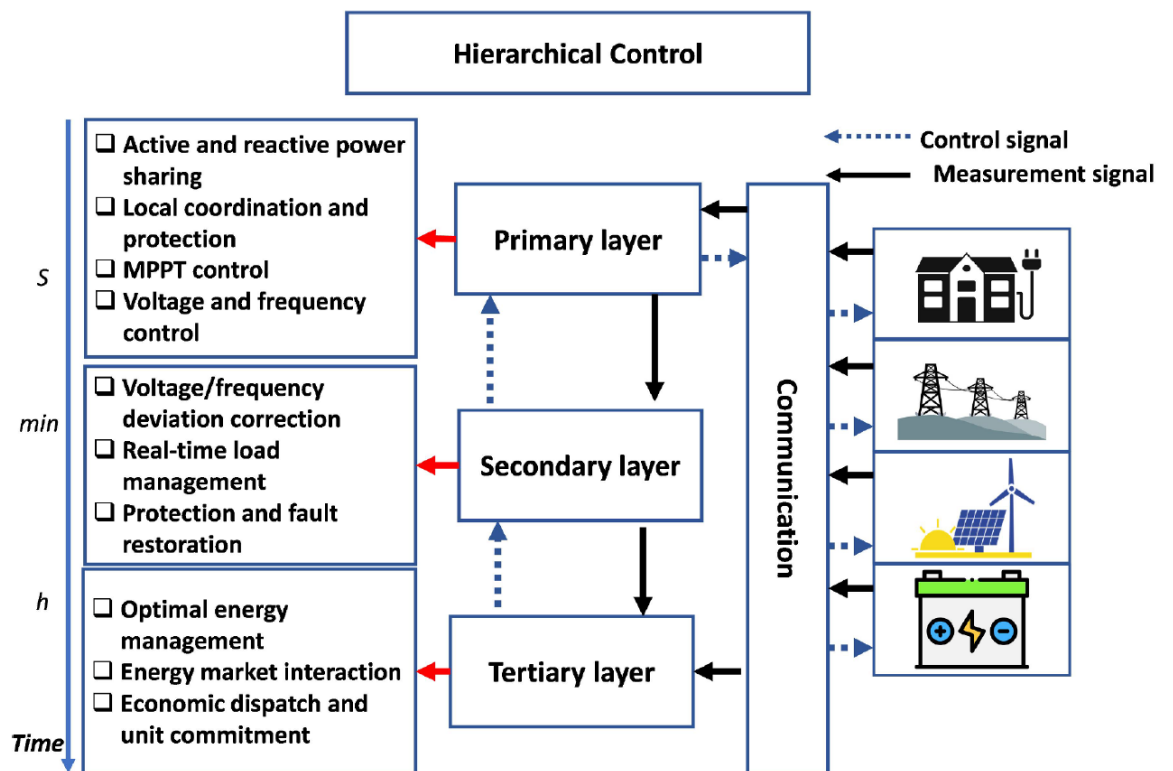


Figure 9 Hierarchical control structure for microgrids

However, further research is needed to fully assess the adaptability of these algorithms to the dynamic nature of evolving energy markets, particularly in response to policy changes and technological advancements (Salehi et al., 2022; Yamashita et al., 2020).

The microgrid design and control literature showcases significant technical progress, effectively demonstrating the potential of advanced architectures.

#### 2.1.3.3 Literature on identifying microgrid barriers and drivers

This section critically evaluates the literature, identifying the key barriers and drivers influencing widespread microgrid adoption, revealing a complex interplay of institutional, policy-driven, and socio-economic factors. Warneryd et al. (2020) emphasise the importance of institutional reforms, particularly clear governance frameworks and regulatory incentives, for fostering community-based microgrids (CBMGs) (Warneryd et al., 2020). While their findings suggest substantial potential for emission reduction and enhanced resilience, their predominantly qualitative approach limits the assessment of scalability and generalisability across diverse political and market structures. Similarly, Gui et al. (2017), employing a New Institutional Economics (NIE) framework, highlight the influence of localised economic and social factors (Gui et al., 2017). Their conceptual model could, however, benefit from a more in-depth exploration of cultural barriers and potential community resistance. The cross-regional analysis conducted by Warneryd & Karltorp (2022) broadens the scope, examining microgrid growth drivers in the USA, EU, Asia, and Australia (Warneryd & Karltorp, 2022). Their comparative approach illustrates the impact of varying policy regimes and market conditions. However, the study could be strengthened by the development of a more cohesive set of best practices or adaptable policy guidelines. Ajaz & Bernell (2021) contribute a valuable analysis of the Californian microgrid transition through the lens of the Multi-Level Perspective (MLP), highlighting the importance of stakeholder engagement and supportive state-level policies (Ajaz & Bernell, 2021). While focused on microgrids in California, this in-depth analysis provides valuable insights into the complex interplay of factors influencing microgrid adoption and offers transferable lessons for other regions. Nevertheless, the focus on California raises questions about the transferability of findings to jurisdictions lacking California's specific resources, technological expertise, or policy environment.

Empirical research by Soshinskaya et al. (2014) identifies real-world barriers and success factors influencing microgrid adoption (Soshinskaya et al., 2014). These real-world insights are crucial for bridging the gap between theoretical models and practical implementation. However, their analysis could be enhanced by a more thorough consideration of long-term project sustainability and the dynamic nature of regulatory environments, particularly in contexts characterised by policy uncertainty. Khodayar (2017) addresses the critical dimension of off-grid microgrids in rural communities, arguing compellingly for their potential as affordable and sustainable alternatives to grid extensions (Khodayar, 2017).

#### 2.1.3.4 Existing literature on regulatory challenges regarding microgrids

A critical assessment of the literature concerning regulatory challenges for microgrid deployment reveals significant variation in scope and geographic focus, potentially limiting broader applicability (Ali et al., 2017; Guibentif & Vuille, 2022). Wouters (2015), for example, focuses on the specific context of Singapore, offering tailored policy recommendations that may not readily translate to regions with differing institutional or market structures (Wouters, 2015). Similarly, Abu-Sharkh et al. (2006) examine the United Kingdom, outlining technical and economic barriers to microgrid expansion (Abu-Sharkh et al., 2006). Costa et al. (2008) advocate for economic incentives (Costa et al., 2008), while Pullins (2019) emphasises institutional reforms, both arguing that well-designed policy measures are crucial for realising the full potential of microgrids (Pullins, 2019). However, the scalability of these reforms, particularly in jurisdictions lacking robust regulatory bodies or established liberalised energy markets, requires further investigation. Parag and Ainspan (2019) explore the advantages and disadvantages of microgrid development in comparison to the costs and benefits of traditional generation connected to a large-scale transmission and distribution network (Parag & Ainspan, 2019). Their analysis could be strengthened by a more comprehensive assessment of factors such as localised resilience and community empowerment, which are often

difficult to quantify but crucial for understanding the full value proposition of microgrids. Additionally, Ustun et al. (2011), in their overview of microgrid standards, highlight the challenge of regulatory frameworks lagging behind technological advancements. This issue is further compounded by the rapid pace of innovation in digital control and communication systems, potentially rendering existing standards obsolete (Ustun et al., 2011).

#### 2.1.4 Summarising the findings

Section 2.1 of this literature review chapter has demonstrated the scope and different dimensions of microgrid research to synthesise key insights from the global microgrids literature on microgrids worldwide. Variations in microgrid definitions stem from the specific applications in which microgrids are deployed—whether for enhancing energy resilience, integrating renewable resources, or providing clean electricity to regional and remote communities. Most definitions emphasise the incorporation of Distributed Energy Resources (DERs), indicating that microgrids are increasingly viewed as pivotal to the energy transition. Additionally, while microgrids are generally considered grid-connected systems, their ability to “island” during main grid outages makes them particularly valuable in rural and remote areas. Some definitions explicitly discuss geographic or system boundaries, whereas others do not, thus allowing microgrids to range in scale from serving fewer than 10 households to supporting communities of 5,000–10,000 inhabitants. This flexibility underscores the broad adaptability of microgrids to diverse contexts. Collectively, the reviewed literature revealed extensive scholarly interest in microgrids, from technical design and operational frameworks to policy and regulatory considerations. Section 2.2 explores the literature on different aspects of community energy projects and social dimensions of renewable energy technologies, thereby highlighting research gaps in Section 2.3, which this thesis seeks to address, offering a meaningful contribution to the field.

## 2.2 Literature on Community Energy Projects

This section of the literature review explores the concepts surrounding community-based renewable energy projects, emphasising the importance of active community engagement in both the planning and implementation stages and the current research being conducted on the topic. The section explores the definition of 'community' when used in the context of 'community energy'. It will also consider local communities' acceptance of renewable energy technologies. This exploration of the literature highlights the critical role of local communities in renewable energy projects.

### 2.2.1 Community Energy and Community Engagement: A Comprehensive Review of the Literature

#### 2.2.1.1 Defining community

The term 'community' is inherently flexible and challenging to define, with researchers asserting that its definition varies depending on the project or the context in which it is applied (Bauwens et al., 2022; Hicks & Ison, 2018; M.Hoffman & Angela High-Pippert, 2010; Walker & Simcock, 2012). This fluidity, while allowing for context-specific interpretations, also creates ambiguity. Walker (2011), in widely cited research, defines community as “a place or neighbourhood where individuals and local governments interact, where the social network is not confined to geographical boundaries, and where a collaborative process exists between individuals to make informed decisions.” His subsequent six-point framework (actor, scale, place, network, process, and identity) provides a useful tool for dissecting the multifaceted nature of community (Walker, 2011). While Walker's framework offers a valuable analytical tool, its comprehensiveness also underscores the inherent complexity of the concept, making it difficult to operationalise in practice. However, the very breadth of these dimensions highlights the challenge of establishing a singular, universally applicable definition. Bauwens et al. (2022), reviewing 405 articles to understand the term, stated that the term "community" is interpreted

inconsistently across the scientific literature, particularly in discussions surrounding concepts like community energy, energy communities, community solar, and community wind (Bauwens et al., 2022). This lack of conceptual clarity underscores the need for researchers to explicitly define their use of the term "community" within each specific context, acknowledging the inherent limitations of any single definition and justifying their chosen approach. This lack of clarity has also led to varying interpretations of the term, making it even harder to define community energy projects.

#### 2.2.1.2 Defining Community Energy Projects

Similarly, defining community energy projects is also complicated because of flexible and polysemous definitions of "community" (Bauwens et al., 2022; Becker & Kunze, 2014; Brummer, 2018; Creamer et al., 2019; Walker, 2011). The lack of conceptual clarity surrounding "community energy" constitutes a significant limitation in academic research, making it an elastic concept with diverse definitions and interpretations (Dóci & Vasileiadou, 2015; Hicks & Ison, 2018; Seyfang et al., 2013). However, researchers have made considerable efforts to define community energy projects. Seyfang et al. (2013), in their highly cited paper, have defined a community energy project as a project in which communities take a high degree of ownership of the project and where communities take control of the energy projects while ensuring that they benefit from the projects (Seyfang et al., 2013). Similarly, Klein & Coffey (2016) define community energy projects as initiatives incorporating Distributed Energy Resources (DERs) for a clean and efficient energy supply, driven by the collective interests of the local community, which also shares the project's benefits, costs, and revenues upon completion (Sharon J.W.Klein & Stephanie Coffey, 2016). Walker et al. (2007) have analysed diverse community renewable energy projects, exploring variations in ownership and outcomes and highlighting the diverse interpretations of "community energy" among stakeholders (Walker G & Cass N, 2007). Walker (2008) has categorised three different views on local community involvement in community energy projects. 1) People who actively participate

in the project's inception, planning, and operation. 2) People who are only interested in the project's outcome, i.e., the project should benefit the community regarding economic and environmental benefits. 3) People who use the term community renewables with any type of project that provides advantages to people (Walker, 2008). Some researchers argue that community energy projects should be defined primarily by their outcomes, such as community mobilisation and shifts in attitudes toward sustainable solutions (Eadson & Foden, 2014).

#### 2.2.1.3 Advantages of community inclusion in renewable energy projects:

Community-owned renewable energy (CRE) projects are recognised for their potential to deliver a range of environmental and local socio-economic benefits (Berka & Creamer, 2018). The strategic value of including diverse and adaptable communities in decision-making processes has been highlighted in the literature (Huang et al., 2015; Loomis & Tonnie, 2017; Walker et al., 2010). These projects also provide a platform for local communities to articulate their economic, social, and environmental objectives while simultaneously contributing to energy system decarbonisation (Gjorgievski et al., 2021). Primarily utilising renewable energy resources as distributed energy resources (DERs), these community energy projects contribute to the energy transition by providing small-scale, decentralised power to local communities (M.Hoffman & Angela High-Pippert, 2010; Oteman et al., 2014; Romero-Rubio & de Andrés Díaz, 2015).

### 2.2.2 Exploring the Multifaceted Dimensions of Community Energy Research

The following section presents a review of the literature on community renewable energy, providing essential context for understanding the role of communities in renewable energy projects. Hewitt et al. (2019), in their extensive mapping of community energy (CE) initiatives across diverse European contexts, offer valuable comparative insights into the landscape of CE projects. However, their predominantly descriptive approach

leaves a gap in understanding how cultural and policy factors influence project outcomes (Hewitt et al., 2019). Klein and Coffey (2016) contribute a valuable theoretical framework that positions Community Energy (CE) initiatives as catalysts for behavioural change, a perspective often underrepresented in purely techno-economic evaluations of microgrid and renewable energy projects (Sharon J.W.Klein & Stephanie Coffey, 2016). Their comprehensive review of over 70 case studies provides a rich, cross-contextual foundation for understanding the diversity of CE approaches. However, this breadth underscores the need for more precise definitions and typologies of CE, given the wide spectrum of ownership models, governance structures, and technological approaches (Sharon J.W.Klein & Stephanie Coffey, 2016).

A critical examination of Gordon Walker and Patrick Devine-Wright's contributions to the literature on community energy reveals both conceptual strengths and certain limitations in their frameworks' applicability across diverse contexts. While their research primarily focused on wind and other renewable energy systems, their insights into community energy and participation have been widely cited in academic literature. Their foundational categorisation of community energy into "process" and "outcome" (Walker & Devine-Wright, 2008) has proven influential, providing a valuable lens for analysing the distribution of agency and benefit within CE initiatives. While this distinction offers conceptual clarity, it may oversimplify the complex dynamics of multi-stakeholder collaboration, particularly in settings where public, private, and third-sector interests converge. Furthermore, Walker's (2008) review of diverse ownership models, including cooperatives and development trusts, effectively demonstrates the potential for community empowerment through direct participation (Walker, 2008). However, the practical implementation of these models is often constrained by factors such as funding limitations, regulatory hurdles, and a lack of readily available local expertise, which can hinder the translation of "ideal" ownership structures into widespread practice.

Walker's (2011) assertion that community engagement fosters social innovation and the collaborative deployment of sustainable technologies highlights the transformative potential of local involvement (Walker, 2011). Walker and Devine-Wright's extensive research highlights the crucial role of social acceptance, trust-building, and shared values in successful community energy initiatives (Shove & Walker, 2016.; Walker, 2007; Walker et al., 2007; Walker G & Cass N, 2007; Walker & Simcock, 2012). Their scholarship offers valuable insights into the factors influencing project acceptance and success. Walker and Devine-Wright's research offers a pivotal contribution to understanding how communities can organise and benefit from renewable energy projects, establishing a crucial theoretical foundation by emphasising the interplay between process and outcome. However, further research is needed to explore the practical application of their frameworks under varying regulatory, financial, and cultural conditions, particularly concerning the challenges of scaling successful local demonstrations to regional or national programs.

Other researchers have also contributed significantly to the community energy literature. Koirala et al. (2018) introduce the concept of Integrated Community Energy Systems (ICESs), offering a contemporary framework for restructuring local energy infrastructures and leveraging distributed energy resources (Koirala et al., 2018). While their approach is innovative, its predominantly conceptual nature leaves open questions regarding practical feasibility and the potential influence of regulatory or socio-cultural barriers on ICES deployment across diverse regions. Van der Schoor and Scholtens (2019) emphasise the need for cross-national coherence in community energy research. While their current research is concentrated in certain European nations, this foundation provides a valuable starting point for broader cross-national investigations (van der Schoor & Scholtens, 2019). Seyfang et al. (2013) contribute valuable empirical insights from a UK-wide survey of community energy projects, offering a useful template for analysing community-led renewable ventures (Seyfang et al., 2013). While this body of

work offers rich, region-specific evidence, it limits the development of a more comprehensive and globally applicable understanding of community energy dynamics. This geographic skew highlights a critical gap in the literature, particularly concerning understudied regions such as Australia. While the body of research on Australian community energy projects has expanded in recent years, a significant gap remains in understanding the complex interplay between the country's unique regulatory environment, market structures, and social attitudes and their influence on the outcomes of community-led energy initiatives.

### 2.2.3 Existing literature on community energy projects in Australia

The transition towards renewable energy sources has gained significant momentum in Australia, prompting various community-driven initiatives aimed at harnessing renewable energy resources (Colvin et al., 2016; Hicks & Ison, 2011; Hill & Connelly, 2018; Hindmarsh & Alidoust, 2019; Mey et al., 2016). Within the context of growing concerns regarding climate change and energy security, community renewable energy (CRE) projects have become strategically important for empowering local communities and diminishing reliance on fossil fuels (Hicks & Ison, 2018). This section of the literature review examines the research on community energy projects in Australia, highlighting relevant studies and insights that will ultimately contribute to understanding community engagement in the microgrid sector.

A critical analysis of the literature on community energy projects in Australia reveals both promising insights and persistent challenges that require further investigation. Mey et al. (2016) emphasise the increasing relevance of community renewable energy for local governments, arguing that such projects have evolved from primarily environmental initiatives to assume a central role in local governance and budget considerations (Mey et al., 2016). Similarly, Hill and Connelly's (2018) analysis of the Clean Energy for Eternity (CEFE) campaign effectively illustrates the potential of strategic community mobilisation

to influence local energy policies. However, the case study approach, while providing valuable in-depth insights, raises questions about the generalisability of these strategies to regions with differing socioeconomic or environmental contexts (Hill & Connelly, 2018). Byrnes et al. (2016) highlight the challenges faced by remote Western Australian communities, including technical capacity constraints, infrastructural limitations, and reliance on local Distribution Network Service Providers (DNSPs) (Byrnes et al., 2016). Colvin et al.'s (2019) examination of a failed wind energy project serves as a cautionary tale, underscoring the critical role of early-stage consultation and public perception. However, their analysis primarily focuses on anticipated impacts, thus overlooking the importance of ongoing community engagement practices and conflict-resolution mechanisms in mitigating project derailment (Colvin et al., 2019).

Studies by Csereklyei et al. (2024) and Uddin et al. (2023) examine the technical and regulatory complexities associated with integrating energy storage and distributed generation at the community scale. Csereklyei et al. (2024) explore the role of community-scale batteries (CSBs) in the energy transition by examining multiple business model case studies alongside a regulatory review (Csereklyei et al., 2024) whereas Uddin et al. (2023) evaluate the techno-economic feasibility of a grid-connected microgrid aimed at providing a low-cost, reliable energy supply to regional areas in Australia (Uddin et al., 2023). While their findings offer promising pathways for cost reduction and system reliability enhancement, social acceptance and local participation appear to be secondary concerns in these predominantly techno-economic analyses. Conversely, Ellis and Farnaz (2022) prioritise household-level experiences with small-scale photovoltaics (sPV) in social housing, providing valuable insights into the impacts of distributed generation on vulnerable populations (Ellis Judson & Farnaz Zirakbash, 2022). Despite these valuable contributions, the transferability of their qualitative findings, particularly concerning energy justice, to broader demographic groups warrants further investigation. While the studies by Andeobu et al. (2024), Hindmarsh & Alidoust

(2019), and Della Bosca & Gillespie (2018) provide valuable insights into the complex interplay between macro-level policy debates and localised community attachments and economic structures by considering diverse socio-political and place-based factors (Andeobu et al., 2024; Della Bosca & Gillespie, 2018; Hindmarsh & Alidoust, 2019), the varied policy regimes across Australian states limit the generalisability of their findings without a more cohesive, nationally scoped analysis. Proudlove et al. (2020), using the Theory of Planned Behaviour, assessed public willingness to invest in community projects, revealing generally positive attitudes toward renewable energy (Proudlove et al., 2020). However, further research is needed to explore how demographic factors and evolving energy prices may influence these attitudes over time. Finally, research by Rioux-Gobeil & Thomassin (2024), Brown et al. (2024), and Urmee et al. (2012) addressed broader sustainability imperatives, including just energy transitions, net-zero buildings, and community-driven reductions in energy and water consumption (Brown et al., 2024; Rioux-Gobeil & Thomassin, 2024; Urmee et al., 2012). While these studies signal a growing interest in systemic transformations, they also highlight the need for deeper integration of social equity considerations and cross-sectoral policy frameworks. Australian scholarship demonstrates that successful community energy projects require not only technological feasibility and local government support but also social acceptance and inclusive stakeholder engagement. Future research needs to address the complex interplay of technical, social, economic, and political factors shaping community energy projects.

#### 2.2.4 Examining literature on community acceptance of renewable energy projects

The successful implementation of renewable energy technologies is influenced by many factors, with 'community acceptance' widely regarded as a critical determinant (Batel, 2020; Toke, 2005). Community acceptance of renewable energy adoption is explored in

the literature, yet it remains an area requiring further research (Batel, 2020; de Abreu D'Aquino et al., 2024; Oh, 2024; Schönauer & Glanz, 2022; Shanmugavel et al., 2022; Taufik & Dagevos, 2021). This section provides a critical analysis of the literature concerning community acceptance, highlighting its crucial role in the adoption of renewable energy technologies.

Wolsink's (2018, 2020) extensive exploration of social acceptance research provides a comprehensive overview of emerging trends and effectively highlights the ongoing fragmentation of theoretical frameworks. This fragmentation, while reflecting the evolving nature of the field, necessitates greater efforts toward theoretical synthesis (Wolsink, 2018)(Wolsink, 2020). Building on these foundations, Minadakis (2014) effectively maps the evolution of the Social License to Operate (SLO) concept from extractive industries to the renewable energy sector, aligning it with Social Acceptance (SA). This cross-sectoral perspective offers a promising framework for understanding acceptance. However, the applicability of SLO frameworks to decentralised energy systems, characterised by distinct ownership patterns and community dynamics, warrants further empirical investigation (Minadakis & Vega-Araújo, 2024). Similarly, Wüstenhagen et al.'s (2007) seminal tripartite model of acceptance (socio-political, community, and market) effectively highlights the relative neglect of market acceptance in their empirical research (Wüstenhagen et al., 2007). While subsequent studies have focused on community and socio-political dimensions, the gap in understanding market-driven barriers and enablers persists, presenting a significant opportunity for future research. Batel et al. (2013) critically examine the limitations of the traditional acceptance paradigm, arguing that community responses to renewable energy infrastructure are multifaceted and not adequately captured by a simplistic, dichotomous view of acceptance or rejection (Batel et al., 2013). Ruggiero et al. (2014) advance this dialogue by highlighting the complex interplay of inter- and intra-community dynamics, demonstrating how even robust local participation can be undermined by conflicting agendas among different stakeholder

groups (Ruggiero et al., 2014). While their emphasis on the mediating role of community leaders and organisations is important, further research is needed to develop systematic strategies for managing and reconciling divergent stakeholder priorities in practice. Hammami et al. (2016) point to perceived community-wide benefits as a crucial driver of local acceptance of renewable energy technologies (Hammami et al., 2016). Finally, while Castillo-Calzadilla et al. (2022) focus on the technical aspects of Low-Voltage Direct Current (LVDC) systems, their findings have important implications for understanding how renewable energy infrastructures are perceived locally. The potential for community-wide benefits and the management of place-based concerns related to LVDC systems represent a promising area for future empirical exploration (Castillo-Calzadilla et al., 2022).

Additionally, a critical review of Ganit's (2023) work on microgrid adoption in Wayuu community in La Guajira, Colombia, reveals a valuable emphasis on the financial drivers of social acceptance. By highlighting affordability as a key determinant of microgrid uptake, the study highlights the often-neglected socioeconomic constraints that can impede community-led energy transitions (Granit, 2023). Tamasiga et al. (2024) make a compelling argument for the potential of renewable energy microgrids to address energy poverty and improve socio-economic conditions in underserved communities. Their findings effectively demonstrate the cost-effectiveness and environmental benefits of small-scale renewable systems, highlighting positive impacts on livelihoods, economic growth, and access to essential services such as health and education (Tamasiga et al., 2024). Adding to this, Fragniere et al. (2023), focusing on the Swiss context, demonstrate how community opposition to smart grids can overshadow perceived technological benefits. The findings highlight the need for more comprehensive policies that prioritise proactive community engagement before the implementation of new energy technologies, rather than simply reacting to opposition after the fact (Fragniere et al., 2023).

This review highlights the multifaceted and context-dependent nature of social acceptance of renewable energy projects. It also reveals the need for more integrated, interdisciplinary research that can comprehensively capture the complex interplay of technological feasibility, place-based attachments, stakeholder dynamics, and broader market forces. Such a holistic approach is essential for refining our understanding of acceptance and ultimately facilitating the development of more equitable, resilient, and community-oriented renewable energy projects.

#### 2.2.4.1 Social acceptance of renewable energy projects in Australia

The increasing deployment of renewable energy technologies in Australia necessitates a thorough understanding of social acceptance, a crucial factor in the successful transition to a sustainable energy future. This section examines the social acceptance of renewable energy projects in Australia, exploring the factors that influence community attitudes and behaviours. D'Souza and Yiridoe (2014) highlight local communities' apprehensions toward wind projects, emphasising how inadequate stakeholder engagement can exacerbate these concerns and impede project implementation (D'Souza & Yiridoe, 2014). While their recommendation for early, transparent community engagement is valuable, a deeper exploration of how cultural, economic, and political contexts shape community reactions is required. Beyond wind energy, Elavarasan et al. (2024) employ multi-criteria decision-making models to rank renewable energy options, concluding that solar technology aligns most closely with national sustainability objectives (Elavarasan et al., 2024). Scovell et al. (2024) offer valuable insights by investigating how broader societal narratives about climate change and energy transitions influence local acceptance of large-scale solar projects (Scovell et al., 2024). This perspective aligns with Devine-Wright's (2007) call for interdisciplinary approaches that explore the symbolic and emotional dimensions of public attitudes (Devine-Wright, 2007). Adams and Prakash (2024) advocate for more inclusive, bottom-up strategies in energy planning, arguing that risk-based, top-down approaches may fail to address

community-specific concerns and social vulnerabilities (Adams & Prakash, 2024). Their study, grounded in stakeholder interviews, provides a rich contextual understanding of how policies can be reshaped to enhance both infrastructural and social resilience. However, the emphasis on sector-level interviews raises concerns about the representation of local residents, particularly marginalised groups, in these dialogues, potentially limiting the generalisability of their findings. Sechilariu et al. (2018), in their research, examine the social acceptance of EV charging stations powered by a microgrid (Sechilariu et al., 2018). Bugden and Stedman (2021) provide empirical evidence that social acceptance of smart grids does not necessarily correlate with time or exposure. Their finding that acceptance can plateau or even decline suggests that robust engagement efforts, while essential, are insufficient if initial community reservations are not adequately addressed (Bugden & Stedman, 2021). This highlights the importance of understanding the *nature* of these reservations and developing targeted strategies to address them. Raman and Peng (2018) highlight the technical barriers to the widespread adoption of Home Energy Management Systems (HEMS), particularly the limitations of current hardware setups and proprietary solutions. Their proposed decentralised building energy management system offers a promising, scalable solution (Raman & Peng, 2018). However, the study could benefit from a more in-depth consideration of how social acceptance evolves in response to technological changes. Finally, Dowd et al. (2011) examine social acceptance of geothermal energy, identifying knowledge gaps and public fears concerning water usage and seismic risks as key barriers to acceptance. (Dowd et al., 2011). While their research highlights the importance of accurate and accessible public information, it assumes a direct correlation between improved awareness and reduced opposition, an assumption that requires further empirical validation.

These studies collectively highlight the multifaceted and context-dependent nature of social acceptance in Australia, pointing to key areas for future research. These include comparative analysis across renewable energy technologies, deeper explorations of the

complex interplay of socio-cultural and techno-economic factors, and the development of robust, methodologically diverse stakeholder engagement frameworks that address the unique concerns of diverse local communities. The literature on social acceptance of renewable energy projects has also revealed that while significant progress has been made in understanding the predictors of acceptance, further research is required to explore underexamined areas, such as social acceptance around microgrids.

## 2.3 Research gaps: Lack of research on the social aspects of microgrids

While Sections 2.1 and 2.2 explored various aspects of microgrids and community energy projects, a notable gap exists in the literature concerning community engagement and the social dimensions of microgrids. Although some research has touched upon these topics, the body of work remains limited. Section 2.3 will, therefore, examine these research gaps, specifically addressing those this thesis seeks to explore.

### 2.3.1 Community microgrids – conceptual analysis and key characteristics

The term *community microgrids* is used to highlight the role of local communities in microgrid projects. However, its meaning varies considerably, reflecting the diverse interpretations of both *community* and *microgrids*, as discussed in Sections 2.1 and 2.2. Given the complexity surrounding the definitions of community, community energy projects, and microgrids, defining a community microgrid is not straightforward. Some researchers use "community microgrid" to emphasise the active role of local communities in the project, highlighting their involvement. In contrast, others define the term more broadly, considering it when the project aims to serve community needs, including local businesses and residential consumers. This section highlights some of the key definitions used in the literature regarding community microgrids.

A highly cited definition of community microgrids has been proposed by Warneryd et al. (2020), defining community microgrids by combining the definitions of microgrids and community energy projects. They defined community microgrids as: *“a community microgrid is technically a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries which act as a single controllable entity with respect to the grid. A community microgrid can connect or disconnect from the grid to enable it to operate in both grid-connected or island mode. Moreover, a community microgrid is connected with its community through physical placement and can be owned by said community or other parts”* (Warneryd et al., 2020). This definition highlights community ownership of microgrid assets as a key criterion for labelling a project as a 'community microgrid.' It has been widely adopted in the literature for its emphasis on place-based microgrids and its advocacy for community ownership. Meena et al., 2019 defined community microgrids as: “microgrids tailored to match the unique energy needs, goals and characteristics of local communities which can be based in various geographical settings such as rural, remote, or urban areas, and encompass diverse types of loads that range from residential and commercial to critical and non-critical (Meena et al., 2019). This definition also considers the microgrid deployment in a particular region to be called a community microgrid. Clean Coalition (2024) has also defined a community microgrid as ‘a coordinated local grid area served by one or more distribution substations and supported by high penetrations of local renewables and other distributed energy resources (DERs) such as energy storage and demand response (Clean Coalition, 2024). The definition, however, neglects the crucial aspect of community engagement and the involvement of local communities in microgrid projects. The distinction between traditional and community microgrids is nuanced, with both types defined by clearly established geographical boundaries, an essential characteristic for all microgrids, regardless of their scale or function (Hirsch et al., 2018). Traditional microgrids typically serve larger or more complex systems, which may span multiple buildings, campuses, or critical infrastructure with diverse operational requirements, but

they still operate within well-defined electrical and geographic limits (Shahbazitabar et al., 2021). Community microgrids, on the other hand, are usually implemented to serve a specific, often smaller, community or neighbourhood, also operating within a distinct geographic area but with a particular focus on local engagement and resilience benefits for that community (Lu et al., 2015). Following a review of the extant literature on community microgrids, the term "community microgrid" will not be employed in this thesis due to the fluid and inconsistently applied nature of the terminology. While numerous researchers have proposed definitions, these definitions appear to be primarily driven by application and use case rather than a consistent set of defining characteristics.

### 2.3.2 Research gaps

The research gaps identified from the previous sections are categorised into three main areas, which have informed the development of the research questions outlined in Chapter 1, Section 1.6.

#### *2.3.2.1 Limited understanding of the current landscape of microgrid projects in Australia*

Microgrid drivers have been well-explored in the academic literature (Hirsch et al., 2018; Onu et al., 2023; Pullins, 2019; Ullah et al., 2020; Wei & Chen, 2019) however, a gap exists in understanding the microgrid landscape in Australia. There has been limited research on the state of microgrids in Australia. Simon et al. (2024) examined the key characteristics of RRCRF-funded projects in Australia, focusing on drivers, stakeholder engagement, ownership, and business models. While their primary focus was on identifying business models for microgrid implementation, the study highlighted that significant work is still needed in the regulatory, financial, and governance domains to fully realise the benefits of microgrids for all stakeholders (Wright et al., 2024). Farrelly & Tawfiq (2019) investigated four microgrid-related experiments in Victoria, Australia, uncovering the drivers and challenges that influenced the success and limitations of

these innovative projects. However, the research was confined to four case studies, emphasising the need for more research on the topic (Farrelly & Tawfik, 2020).

### **Insufficient analysis of the drivers and barriers to microgrid adoption in the Australian policy and regulatory environment.**

Similarly, the barriers that hinder the more rapid deployment of microgrids have been explored extensively in the academic literature (Brummer, 2018; Cagnano et al., 2020; Gui et al., 2017; Guibentif & Vuille, 2022; Lukas Weber, 1997; Soshinskaya et al., 2014; Wouters, 2015). The existing literature stated the absence of a suitable regulatory framework (Farrelly & Tawfik, 2020; Marnay & Giri Venkataramanan, 2006; Wouters, 2015; Wright et al., 2024) determining a viable business model and ownership structure (F.G. Reis et al., 2021; Hanna et al., 2017), lack of capital and access to funding (Guerrero M. Josep et al., 2013; Lukas Weber, 1997; Soshinskaya et al., 2014) and lack of trust between the local community representatives and the project team can be a significant barrier to the microgrid deployment (Coy et al., 2021; Gambetta, 1988; Walker et al., 2010). Additionally, some studies have explored the drivers, barriers, and community engagement in microgrid projects in U.S (Ajaz, 2019; Ajaz & Bernell, 2021; Muttaqee et al., 2023). However, the details about the barriers in Australian microgrids have not been explored in the literature except by a few researchers. The comprehensive analysis of drivers and barriers of microgrids has been presented in Chapter 4 to fill this gap and answer the research question: “What are the major barriers and opportunities in microgrid-related studies in Australia, and how do these compare to those assumed in the international literature?”

#### *2.3.2.2 Limited Research on the role of community engagement*

As highlighted in Section 2.2, extensive research has been conducted on community energy projects both globally and in Australia. However, a significant gap remains in understanding the importance of community engagement in microgrid projects. While

there is some limited research covering this topic, it remains largely underexplored and therefore requires further research (Chalaye et al., 2023; Muttaqee et al., 2023; Valencia et al., 2021). As Australia transitions towards a more decentralised energy future, the active involvement and influence of local communities are increasingly recognised for the successful implementation of microgrids. Pierrick et al. (2023) propose an integrated site selection methodology for microgrids which considers the local socio-political context and community concerns. Their research aims to further democratise the deployment of network integration technology by addressing energy vulnerabilities and inequalities while incorporating the perspectives of the most affected and vulnerable stakeholders into informed, place-based deliberative processes (Chalaye et al., 2023). Although the study primarily focuses on developing a method for place-based site selection for community microgrids, it also highlights the existing disconnect between regulatory and industrial sectors and public needs. The authors further argue that site selection should be viewed as a socio-technical process embedded in diverse values, which, if not treated equitably, can lead to tensions and conflicts. They also emphasise the importance of participatory and transparent dialogue at every stage of the site selection process, ensuring discussions are documented and accessible to all stakeholders.

Melissa et al. (2023) explore existing literature on community microgrids, focusing on the representation and inclusion of community preferences across the development stages while proposing a conceptual-theoretical framework based on social capital theory for identifying community characteristics (Eklund et al., 2023). The proposed framework comprises four components: social capital, community capability, community type, and microgrid impact. By integrating technical and social perspectives, the research proposed to operate community microgrids in a manner that maximises benefits for both the community and external stakeholders. Eklund et al. (2024), in another research on community microgrids, introduced a Multi-Criteria Decision Analysis (MCDA) framework for systematically evaluating and aligning business models for community microgrids

within local energy markets (Eklund et al., 2024). By focusing on the integration of community social capital, the research provides valuable insights into the sustainable and efficient development of community microgrids. Additionally, it highlighted the intricate interplay between technological, economic, and social dimensions in community microgrid projects. Eklund et al. (2025), in another research, introduce an innovative method for incorporating social dynamics into the design of community microgrids using Mixed-Integer Linear Programming (MILP). The research highlights how various Business Model Attributes (BMAs) impact both the operational efficiency and social outcomes of community microgrids, offering valuable insights into the development of more sustainable and inclusive energy systems. In another research on microgrids, Farrelly and Tawfik (2020) investigate four microgrid-related projects in Victoria, identifying key drivers and challenges associated with their implementation. The findings indicate that the majority of the challenges were in relation to socio-institutional contexts rather than technological feasibility. The study emphasises the critical importance of addressing institutional and governance issues and highlights the need for further research into the social aspects of microgrids for their successful deployment. Simon et al. (2024), in their research, use a strategic niche management framework to examine microgrid projects in Australia. This research identifies key characteristics of these projects, encompassing drivers, stakeholder engagement, ownership structures, and business models. However, its primary focus lies in analysing ownership structures and business models, revealing the significant impact of legacy regulations and established market actors within the Australian context.

Thus, a review of the literature shows that limited research has been undertaken on identifying and evaluating the impacts of current community engagement strategies employed in recent microgrid projects in Australia's regional and remote communities. This gap necessitates further investigation to inform best practices and optimise community engagement for future microgrid deployments. This thesis contributes to

filling this gap, with Chapters 4, 5, and 6 providing detailed analyses of community engagement in the context of microgrid development.

### *2.3.2.3 Lack of research on social acceptance of microgrids and understanding the factors responsible for hindering or promoting social acceptance*

Despite the growing importance of microgrids in the energy transition, a significant research gap exists concerning their community acceptance and the social factors influencing the acceptance. While research has explored social acceptance in relation to other renewable energy technologies, such as solar (Scovell et al., 2024), wind (Colvin et al., 2016c; Mhairi Aitken, 2010), community batteries (Csereklyei et al., 2024), hydrogen production (Scovell & Walton, 2024), and geothermal technology (Dowd et al., 2011), limited project-based research has been conducted on microgrids specifically, particularly in Australia. A comprehensive understanding of community perceptions around microgrids and the factors influencing support or opposition to these systems, including the complex role of community engagement, is crucial and requires more investigation.

## 2.4 Conclusion

This chapter has reviewed the academic discourse on microgrids, emphasising their social dimensions. While substantial literature exists on the techno-economic aspects of microgrids (Section 2.1) and community renewable energy projects (Section 2.2), research exploring the social dynamics of microgrids in Australia remains limited (Section 2.3). This gap necessitates further investigation into the crucial role of community engagement in successful microgrid implementation within Australia. Subsequent chapters address these gaps and answer the research questions outlined in Section 1.6. Chapter 3 outlines the methodology employed in this thesis to address the identified gaps and provide insights for the effective investigation of microgrid implementations in Australia.

## 2.5 References

- A. Alfergani, K. A. Alfaitori, A. Khalil, & N. Buaossa. (2018). Control strategies in AC microgrid: A brief review. *9th International Renewable Energy Congress (IREC)*, 1–6. <https://doi.org/10.1109/IREC.2018.8362575>.
- A. Mohammed, S. S. Refaat, S. Bayhan, & H. Abu-Rub. (2019). AC Microgrid Control and Management Strategies: Evaluation and Review. *IEEE Power Electronics Magazine*, 6(2), 18–31. <https://doi.org/10.1109/MPEL.2019.2910292>.
- Abdellatif Elmouatamid, Radouane Ouladsine, Mohamed Bakhouya, Najib El Kamoun, Mohammed Khaidar, & Khalid Zine-Dine. (2020). Review of control and energy management approaches in micro-grid systems. *Energies*, 14(1). <https://doi.org/10.3390/en14010168>
- Abu-Sharkh, S., Arnold, R. J., Kohler, J., Li, R., Markvart, T., Ross, J. N., Steemers, K., Wilson, P., & Yao, R. (2006). Can microgrids make a major contribution to UK energy supply? *Renewable and Sustainable Energy Reviews*, 10(2), 78–127. <https://doi.org/10.1016/j.rser.2004.09.013>
- Adams, S., & Prakash, A. (2024). Climate change adaptation in the Australian electricity sector and the lure of resilience thinking. *Energy Research and Social Science*, 118. <https://doi.org/10.1016/j.erss.2024.103755>
- Ajaz, W. (2019). Resilience, environmental concern, or energy democracy? A panel data analysis of microgrid adoption in the United States. *Energy Research and Social Science*, 49, 26–35. <https://doi.org/10.1016/j.erss.2018.10.027>
- Ajaz, W., & Bernell, D. (2021). California's adoption of microgrids: A tale of symbiotic regimes and energy transitions. *Renewable and Sustainable Energy Reviews*, 138. <https://doi.org/10.1016/j.rser.2020.110568>

- Ali, A., Li, W., Hussain, R., He, X., Williams, B., & Memon, A. (2017). Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China. *Sustainability*, 9(7), 1146. <http://dx.doi.org/10.3390/su9071146>
- Andeobu, L., Wibowo, S., & Grandhi, S. (2024). Renewable hydrogen for the energy transition in Australia - Current trends, challenges and future directions. In *International Journal of Hydrogen Energy* (Vol. 87, pp. 1207–1223). Elsevier Ltd. <https://doi.org/10.1016/j.ijhydene.2024.08.499>
- Anderson, K., Farthing, A., Elgqvist, E., & Warren, A. (2022). Looking beyond bill savings to equity in renewable energy microgrid deployment. *Renewable Energy Focus*, 41, 15–32. <https://doi.org/10.1016/j.ref.2022.02.001>
- Andy Haun. (2018). *Micro or Mini: There's a Grid Type for Every Energy Need*. Microgrid Knowledge. <https://www.microgridknowledge.com/resources/microgrid-perspectives/article/11429787/micro-or-mini-theres-a-grid-type-for-every-energy-need>
- Asmus, P. (2010). Microgrids, Virtual Power Plants and Our Distributed Energy Future. *Electricity Journal*, 23(10), 72–82. <https://doi.org/10.1016/j.tej.2010.11.001>
- B. Richter, E. Mengelkamp, & C. Weinhardt. (2019). Vote for your energy: a market mechanism for local energy markets based on the consumers' preferences. *16th International Conference on the European Energy Market (EEM)*, 1–6. <https://doi.org/doi:10.1109/EEM.2019.8916544>.
- Basak, P., Chowdhury, S., Halder Nee Dey, S., & Chowdhury, S. P. (2012). A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid. *Renewable and Sustainable Energy Reviews*, 16(8), 5545–5556. <https://doi.org/10.1016/j.rser.2012.05.043>

- Batel, S. (2020). Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research & Social Science*, 68, 101544. <https://doi.org/https://doi.org/10.1016/j.erss.2020.101544>
- Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infrastructures: A critical discussion. *Energy Policy*, 58, 1–5. <https://doi.org/10.1016/j.enpol.2013.03.018>
- Bauwens, T., Schraven, D., Drawing, E., Radtke, J., Holstenkamp, L., Gotchev, B., & Yildiz, Ö. (2022). Conceptualizing community in energy systems: A systematic review of 183 definitions. *Renewable and Sustainable Energy Reviews*, 156(December 2021), 111999. <https://doi.org/10.1016/j.rser.2021.111999>
- Becker, S., & Kunze, C. (2014). Transcending community energy: collective and politically motivated projects in renewable energy (CPE) across Europe. *People, Place and Policy Online*, 8(3), 180–191. <https://doi.org/10.3351/ppp.0008.0003.0004>
- Berka, A. L., & Creamer, E. (2018). Taking stock of the local impacts of community owned renewable energy: A review and research agenda. *Renewable and Sustainable Energy Reviews*, 82(October 2016), 3400–3419. <https://doi.org/10.1016/j.rser.2017.10.050>
- Bloomberg NEF. (2024). *Japan Energy Transition*.
- Brown, D., Tokede, O., Li, H. X., & Edwards, D. (2024). A systematic review of barriers to implementing net zero energy buildings in Australia. In *Journal of Cleaner Production* (Vol. 467). Elsevier Ltd. <https://doi.org/10.1016/j.jclepro.2024.142910>
- Brummer, V. (2018). Community energy – benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces. *Renewable and Sustainable Energy Reviews*, 94(June), 187–196. <https://doi.org/10.1016/j.rser.2018.06.013>

- Bugden, D., & Stedman, R. (2021). Unfulfilled promise: social acceptance of the smart grid. *Environmental Research Letters*, 16(3), 34019. <https://doi.org/10.1088/1748-9326/abd81c>
- Byrnes, L., Brown, C., Wagner, L., & Foster, J. (2016). Reviewing the viability of renewable energy in community electrification: The case of remote Western Australian communities. In *Renewable and Sustainable Energy Reviews* (Vol. 59, pp. 470–481). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2015.12.273>
- Cagnano, A., De Tuglie, E., & Mancarella, P. (2020). Microgrids: Overview and guidelines for practical implementations and operation. *Applied Energy*, 258(October 2019), 114039. <https://doi.org/10.1016/j.apenergy.2019.114039>
- Castillo-Calzadilla, T., Cuesta, M. A., Olivares-Rodriguez, C., Macarulla, A. M., Legarda, J., & Borges, C. E. (2022). Is it feasible a massive deployment of low voltage direct current microgrids renewable-based? A technical and social sight. In *Renewable and Sustainable Energy Reviews* (Vol. 161). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2022.112198>
- Chalaye, P., Sturmberg, B., Ransan-Cooper, H., Lucas-Healey, K., Russell, A. W., Hendriks, J., Hansen, P., O'Neill, M., Crowfoot, W., & Shorten, P. (2023). Does site selection need to be democratized? A case study of grid-tied microgrids in Australia. *Energy Policy*, 183(April), 113854. <https://doi.org/10.1016/j.enpol.2023.113854>
- Clean Coalition. (2024). *Community microgrid*. <https://clean-coalition.org/community-microgrids/>
- Colvin, R. M., Witt, G. B., & Lacey, J. (2016). How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. *Energy Policy*, 98, 483–494. <https://doi.org/10.1016/j.enpol.2016.09.022>

- Colvin, R. M., Witt, G. B., Lacey, J., & Witt, K. (2019). The community cost of consultation: Characterising the qualitative social impacts of a wind energy development that failed to proceed in Tasmania, Australia. *Environmental Impact Assessment Review*, 77, 40–48. <https://doi.org/10.1016/j.eiar.2019.03.007>
- Costa, P. M., Matos, M. A., & Peças Lopes, J. A. (2008). Regulation of microgeneration and microgrids. *Energy Policy*, 36(10), 3893–3904. <https://doi.org/10.1016/j.enpol.2008.07.013>
- Coy, D., Malekpour, S., Saeri, A. K., & Dargaville, R. (2021). Rethinking community empowerment in the energy transformation: A critical review of the definitions, drivers and outcomes. *Energy Research and Social Science*, 72(December 2020), 101871. <https://doi.org/10.1016/j.erss.2020.101871>
- Creamer, E., Taylor Aiken, G., van Veelen, B., Walker, G., & Devine-Wright, P. (2019). Community renewable energy: What does it do? Walker and Devine-Wright (2008) ten years on. *Energy Research & Social Science*, 57, 101223. <https://doi.org/10.1016/j.erss.2019.101223>
- Csereklyei, Z., Dwyer, S., Kallies, A., & Economou, D. (2024). The role of community-scale batteries in the energy transition: Case studies from Australia's National Electricity Market. *Journal of Energy Storage*, 93. <https://doi.org/10.1016/j.est.2024.112277>
- Daniel Schnitzer, Deepa Shinde Lounsbury, Juan Pablo Carvallo, R. D., Jay Apt, and D. M. K., Schnitzer, D., Deepa, S., Carvalo, J. P., Ranjit, D., Jay, A., & Daniel, K. (2014). Microgrids for Rural Electrification : A critical review of best practices based on seven case studies Microgrids for Rural Electrification : A critical review of best practices. *United Nations Foundation*, 122.
- Darghouth, N. R., Barbose, G., Zuboy, J., Gagnon, P. J., Mills, A. D., & Bird, L. (2020). Demand charge savings from solar PV and energy storage. *Energy Policy*, 146(2020), 111766. <https://doi.org/10.1016/j.enpol.2020.111766>

- de Abreu D'Aquino, C., Moretto, E. M., Zwartjes, N. M., Lenin da Silva, L., & Sachet, H. D. (2024). Design thinking methodology application to develop social acceptance questionnaire for renewable technologies. *Social Sciences & Humanities Open*, *10*, 100912. <https://doi.org/https://doi.org/10.1016/j.ssaho.2024.100912>
- Della Bosca, H., & Gillespie, J. (2018). The coal story: Generational coal mining communities and strategies of energy transition in Australia. *Energy Policy*, *120*, 734–740. <https://doi.org/10.1016/j.enpol.2018.04.032>
- Devine-Wright, P. (2007). Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. *Architecture, Working Pa*(February), 1–15. [http://geography.exeter.ac.uk/beyond\\_nimbyism/deliverables/bn\\_wp1\\_4.pdf](http://geography.exeter.ac.uk/beyond_nimbyism/deliverables/bn_wp1_4.pdf)
- Dóci, G., & Vasileiadou, E. (2015). “Let’s do it ourselves” Individual motivations for investing in renewables at community level. *Renewable and Sustainable Energy Reviews*, *49*, 41–50. <https://doi.org/10.1016/j.rser.2015.04.051>
- Dowd, A. M., Boughen, N., Ashworth, P., & Carr-Cornish, S. (2011). Geothermal technology in Australia: Investigating social acceptance. *Energy Policy*, *39*(10), 6301–6307. <https://doi.org/10.1016/j.enpol.2011.07.029>
- D’Souza, C., & Yiridoe, E. K. (2014). Social acceptance of wind energy development and planning in rural communities of Australia: A consumer analysis. *Energy Policy*, *74*(C), 262–270. <https://doi.org/10.1016/j.enpol.2014.08.035>
- Eadson, W., & Foden, M. (2014). Editorial: critical perspectives on community energy. *People, Place and Policy Online*, *8*(3), 145–148. <https://doi.org/10.3351/ppp.0008.0003.0001>
- Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2023). Energy Research & Social Science Understanding the community in community microgrids: A conceptual framework for better decision-making. *Energy Research & Social Science*, *104*(August), 103260. <https://doi.org/10.1016/j.erss.2023.103260>

- Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2024). Community microgrids: A decision framework integrating social capital with business models for improved resiliency. *Applied Energy*, 367. <https://doi.org/10.1016/j.apenergy.2024.123458>
- Eklund, M., Voinov, A., Hossain, M. J., & Khalilpour, K. (2025). Evaluating the interplay of community behaviour and microgrid design through optimisation modelling in local energy markets. *Renewable and Sustainable Energy Reviews*, 210, 115271. <https://doi.org/https://doi.org/10.1016/j.rser.2024.115271>
- Elavarasan, R. M., Nadarajah, M., & Shafiullah, G. M. (2024). Multi-criteria decision analysis of clean energy technologies for envisioning sustainable development goal 7 in Australia: Is solar energy a game-changer? *Energy Conversion and Management*, 321. <https://doi.org/10.1016/j.enconman.2024.119007>
- Ellis Judson, & Farnaz Zirakbash. (2022). Investigating the potential of solar energy for low-income communities in Australia to reduce hardship, debt and inequality. *Energy Research & Social Science*. <https://doi.org/10.1016/j.erss.2021.102386>
- F. Nejabatkhah, & Y. W. Li. (2015). Overview of Power Management Strategies of Hybrid AC/DC Microgrid. *IEEE Transactions on Power Electronics*, 30(12), 7072–7089. <https://doi.org/10.1109/TPEL.2014.2384999>.
- Farrelly, M. A., & Tawfik, S. (2020). Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renewable and Sustainable Energy Reviews*, 117(October 2019), 109491. <https://doi.org/10.1016/j.rser.2019.109491>
- Feng, W., Jin, M., Liu, X., Bao, Y., Marnay, C., Yao, C., & Yu, J. (2018). A review of microgrid development in the United States – A decade of progress on policies, demonstrations, controls, and software tools. *Applied Energy*, 228, 1656–1668. <https://doi.org/10.1016/j.apenergy.2018.06.096>

- F.G. Reis, I., Gonçalves, I., A.R. Lopes, M., & Henggeler Antunes, C. (2021). Business models for energy communities: A review of key issues and trends. *Renewable and Sustainable Energy Reviews*, 144(October 2020). <https://doi.org/10.1016/j.rser.2021.111013>
- Fragniere, E., Sandoz, S., Abdenadher, N., Moussa, M., Di Marzo Serugendo, G., & Glass, P. (2023). Improving the Social Acceptability of Microgrids. *2023 IEEE Renewable Energy and Sustainable E-Mobility Conference (RESEM)*, 1–5. <https://doi.org/10.1109/RESEM57584.2023.10236324>
- Gambetta, D. (1988). *Trust: making and breaking cooperative relations*. Basil Blackwell. <https://www.worldcat.org/title/trust-making-and-breaking-cooperative-relations/oclc/16833024>
- Gjorgievski, V. Z., Cundeva, S., & Georghiou, G. E. (2021). Social arrangements, technical designs and impacts of energy communities: A review. *Renewable Energy*, 169, 1138–1156. <https://doi.org/10.1016/j.renene.2021.01.078>
- Government of Canada. (2024). *Microgrids Canada*.
- Granit, I. (2023). What makes Colombia's indigenous peoples adopt microgrids? Social acceptance and financial constraints in renewable energy diffusion. *Energy Research and Social Science*, 101. <https://doi.org/10.1016/j.erss.2023.103132>
- Guerrero M. Josep, Juan C. Vasquez, Mehdi Savaghebi, E. G. Carrasco, & Teodorescu, R. (2013). Modeling, Analysis, and Design of Stationary Reference Frame Droop Controlled Parallel Three-Phase Voltage Source Inverters. *IEEE Transactions on Industrial Electronics*, 60(4), 1271–1280. <https://doi.org/10.1109/ICPE.2011.5944601>
- Guerrero M. Josep, & Kandari Ritu. (2021). *Microgrids: Modeling, Control and Applications*. Academic Press.
- Gui, E. M., Diesendorf, M., & MacGill, I. (2017). Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renewable and*

- Sustainable Energy Reviews*, 72(October 2016), 1355–1365.  
<https://doi.org/10.1016/j.rser.2016.10.047>
- Guibentif, T. M. M., & Vuille, F. (2022). Prospects and barriers for microgrids in Switzerland. *Energy Strategy Reviews*, 39, 100776. <https://doi.org/10.1016/j.esr.2021.100776>
- Hadjidemetriou, L., L. Zacharia, E. Kyriakides, B. Azzopardi, S. Azzopardi, R. Mikalauskiene, S. Al-Agtash, M. Al-hashem, A. Tsolakis, & D. Ioannidis. (2018). Design factors for developing a university campus microgrid. *IEEE International Energy Conference (ENERGYCON)*, 1–6. <https://doi.org/10.1109/ENERGYCON.2018.8398791>.
- Hammami, S. M., Chtourou, S., & Triki, A. (2016). Identifying the determinants of community acceptance of renewable energy technologies: The case study of a wind energy project from Tunisia. In *Renewable and Sustainable Energy Reviews* (Vol. 54, pp. 151–160). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2015.09.037>
- Hanna, R., Ghonima, M., Kleissl, J., Tynan, G., & Victor, D. G. (2017). Evaluating business models for microgrids: Interactions of technology and policy. *Energy Policy*, 103(January), 47–61. <https://doi.org/10.1016/j.enpol.2017.01.010>
- Hatziargyriou, N. (2013). *Microgrids: Architectures and Control*. John Wiley and Sons.
- Heidari, R., Seron, M. M., & Braslavsky, J. H. (2017). Ultimate boundedness and regions of attraction of frequency droop controlled microgrids with secondary control loops. *Automatica*, 81, 416–428. <https://doi.org/10.1016/j.automatica.2016.12.021>
- Hewitt, R. J., Bradley, N., Compagnucci, A. B., Barlagne, C., Ceglaz, A., Cremades, R., McKeen, M., Otto, I. M., & Slee, B. (2019). Social innovation in community energy in Europe: A review of the evidence. In *Frontiers in Energy Research* (Vol. 7, Issue APR). Frontiers Media S.A. <https://doi.org/10.3389/fenrg.2019.00031>
- Hicks, J., & Ison, N. (2011). Community-owned renewable energy (CRE): Opportunities for rural Australia. *Rural Society*, 20(3), 244–255. <https://doi.org/10.5172/rsj.20.3.244>

- Hicks, J., & Ison, N. (2018). An exploration of the boundaries of 'community' in community renewable energy projects: Navigating between motivations and context. *Energy Policy*, 113, 523–534. <https://doi.org/10.1016/j.enpol.2017.10.031>
- Hill, D., & Connelly, S. (2018). Community energies: Exploring the socio-political spatiality of energy transitions through the Clean Energy for Eternity campaign in New South Wales Australia. *Energy Research and Social Science*, 36, 138–145. <https://doi.org/10.1016/j.erss.2017.11.021>
- Hindmarsh, R., & Alidoust, S. (2019). Rethinking Australian CSG transitions in participatory contexts of local social conflict, community engagement, and shifts towards cleaner energy. *Energy Policy*, 132(November 2017), 272–282. <https://doi.org/10.1016/j.enpol.2019.05.035>
- Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and Sustainable Energy Reviews*, 90(September 2017), 402–411. <https://doi.org/10.1016/j.rser.2018.03.040>
- Horizon Grand View Research. (2024a). *Canada Microgrid Market Size & Outlook, 2023-2030*.
- Horizon Grand View Research. (2024b). *China Microgrid Market Size & Outlook, 2023-2030*.
- Horizon Grand View Research. (2024c). *Global Microgrid Market Size & Outlook*.
- Hossain, M. A., Pota, H. R., Hossain, M. J., & Blaabjerg, F. (2019). Evolution of microgrids with converter-interfaced generations: Challenges and opportunities. *International Journal of Electrical Power and Energy Systems*, 109(February), 160–186. <https://doi.org/10.1016/j.ijepes.2019.01.038>
- Hotaling, C., Bird, S., & Heintzelman, M. D. (2021). Willingness to pay for microgrids to enhance community resilience. *Energy Policy*, 154(March), 112248. <https://doi.org/10.1016/j.enpol.2021.112248>

- Huang, Z., Yu, H., Peng, Z., & Zhao, M. (2015). Methods and tools for community energy planning: A review. *Renewable and Sustainable Energy Reviews*, 42(4800), 1335–1348. <https://doi.org/10.1016/j.rser.2014.11.042>
- IEEE Spectrum. (2021). *Post-Fukushima Japanese microgrids*. <https://spectrum.ieee.org/postfukushima-japanese-companies-build-microgrids>
- Jiayi, H., Chuanwen, J., & Rong, X. (2008). A review on distributed energy resources and MicroGrid. *Renewable and Sustainable Energy Reviews*, 12(9), 2472–2483. <https://doi.org/10.1016/j.rser.2007.06.004>
- Kabalci, E. (2018). An islanded hybrid microgrid design with decentralized DC and AC subgrid controllers. *Energy*, 153, 185–199. <https://doi.org/10.1016/j.energy.2018.04.060>
- Khodayar, M. E. (2017). Rural electrification and expansion planning of off-grid microgrids. *Electricity Journal*, 30(4), 68–74. <https://doi.org/10.1016/j.tej.2017.04.004>
- Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, 37(7), 1208–1221. <https://doi.org/10.1016/j.worlddev.2008.11.005>
- Koirala, B. P., van Oost, E., & van der Windt, H. (2018). Community energy storage: A responsible innovation towards a sustainable energy system? *Applied Energy*, 231(June), 570–585. <https://doi.org/10.1016/j.apenergy.2018.09.163>
- Lasseter, R., Akhil, A., Marnay, C., Stephens, J., Dagle, J., Guttromson, R., & Meliopoulos A. (2002). The CERTS microgrid concept. *White Paper for Transmission Reliability Program, Office of Power Technologies, US Department of Energy*, 2(3), 30f Energy,.
- Lasseter, R. H., & Paigi, P. (2004). Microgrid: A conceptual solution. *PESC Record - IEEE Annual Power Electronics Specialists Conference*, 6, 4285–4290. <https://doi.org/10.1109/PESC.2004.1354758>

- Limouni, T., Yaagoubi, R., Bouziane, K., Guissi, K., & Baali, E. H. (2025). A comprehensive review of microgrid control methods: Focus on AI, optimization, and predictive techniques. *Computers and Electrical Engineering*, 125. <https://doi.org/10.1016/j.compeleceng.2025.110442>
- Loomis, C. P., & Tonnies, F. (2017). *Community and Society*. Taylor & Francis Group.
- Lu, X., Bahramirad, S., Wang, J., & Chen, C. (2015). Bronzeville Community Microgrids: A Reliable, Resilient and Sustainable Solution for Integrated Energy Management with Distribution Systems. *Electricity Journal*, 28(10), 29–42. <https://doi.org/10.1016/j.tej.2015.11.009>
- Lu, X., Wang, J., & Guo, L. (2016). Using microgrids to enhance energy security and resilience. *Electricity Journal*, 29(10), 8–15. <https://doi.org/10.1016/j.tej.2016.11.013>
- Lukas Weber. (1997). Some reflections on barriers to the efficient use of energy. *Energy Policy*, 25(10), 833–835. [https://doi.org/10.1016/S0301-4215\(97\)00084-0](https://doi.org/10.1016/S0301-4215(97)00084-0)
- M. Lonkar, & S. Ponnaluri. (2015). An overview of DC microgrid operation and control. *IREC2015 The Sixth International Renewable Energy Congress*, 1–6. <https://doi.org/10.1109/IREC.2015.7110892>.
- Madureira, A. G. (2010). *Coordinated and optimized voltage management of distribution networks with multi-microgrids* [Doctoral Dissertation]. Universidade do Porto (Portugal)).
- Markets and Markets. (2024). *Microgrid Market Size, Share, and Growth Analysis*.
- Marnay, C., & Giri Venkataramanan. (2006). *Microgrids in the Evolving Electricity Generation and Delivery Infrastructure*.
- Martin-Martínez, F., Sánchez-Miralles, A., & Rivier, M. (2016). A literature review of Microgrids: A functional layer based classification. *Renewable and Sustainable Energy Reviews*, 62, 1133–1153. <https://doi.org/10.1016/j.rser.2016.05.025>

- Meena, N. K., Yang, J., & Zacharis, E. (2019). Optimisation framework for the design and operation of open-market urban and remote community microgrids. *Applied Energy*, 252. <https://doi.org/10.1016/j.apenergy.2019.113399>
- Meje, K. C., Bokopane, L., & Kusakana, K. (2020). Microgrids control strategies: A survey of available literature. *2020 8th International Conference on Smart Grid and Clean Energy Technologies, ICSGCE 2020, 2020, 167–173*. <https://doi.org/10.1109/ICSGCE49177.2020.9275651>
- Mey, F., Diesendorf, M., & MacGill, I. (2016). Can local government play a greater role for community renewable energy? A case study from Australia. *Energy Research and Social Science*, 21, 33–43. <https://doi.org/10.1016/j.erss.2016.06.019>
- Mhairi Aitken. (2010). Wind power and community benefits: Challenges and opportunities. *Energy Policy*, 38(10), 6066–6075. <https://doi.org/10.1016/j.enpol.2010.05.062>
- M.Hoffman, S., & Angela High-Pippert. (2010). From private lives to collective action: Recruitment and participation incentives for a community energy program. *Energy Policy*, 38(12), 7567–7574. <https://doi.org/10.1016/j.enpol.2009.06.054>
- Microgrid Knowledge. (2024a). *New Infrastructure Act Funding Release*.
- Microgrid Knowledge. (2024b). *What the US Infrastructure Deal Does for Microgrids*.
- Minadakis, P., & Vega-Araújo, J. (2024). Rethinking the social license to operate? A theoretical exploration of its synergies with social acceptance and energy justice for a just transition. In *Energy Research and Social Science* (Vol. 113). Elsevier Ltd. <https://doi.org/10.1016/j.erss.2024.103552>
- More Microgrids. (2009). Report on the technical, social, economic, and environmental benefits provided by Microgrids on power system operation. *WPG. Evaluation of the System Performance on Power System Operation*, analysis of technical, social, economic and environ.

- Muttaqee, M., Furqan, M., & Boudet, H. (2023). Community response to microgrid development: Case studies from the U.S. *Energy Policy*, 181(December 2022), 113690. <https://doi.org/10.1016/j.enpol.2023.113690>
- NYSERDA. (2021).
- Oh, C. (2024). Contestation in social acceptance of direct air capture (DAC) technologies in Korea by differing framings over governance principles. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(4), 100403. <https://doi.org/https://doi.org/10.1016/j.joitmc.2024.100403>
- Onu, U. G., Zambroni de Souza, A. C., & Bonatto, B. D. (2023). Drivers of microgrid projects in developed and developing economies. *Utilities Policy*, 80(December 2022), 101487. <https://doi.org/10.1016/j.jup.2022.101487>
- Oteman, M., Wiering, M., & Helderma, J. K. (2014). The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. *Energy, Sustainability and Society*, 4(1), 1–17. <https://doi.org/10.1186/2192-0567-4-11>
- Parag, Y., & Ainspan, M. (2019). Sustainable microgrids: Economic, environmental and social costs and benefits of microgrid deployment. *Energy for Sustainable Development*, 52, 72–81. <https://doi.org/10.1016/j.esd.2019.07.003>
- Perez-DeLaMora, D. A., Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. G. (2021). Roadmap on community-based microgrids deployment: An extensive review. *Energy Reports*, 7, 2883–2898. <https://doi.org/10.1016/j.egyr.2021.05.013>
- Planas, E., Andreu, J., Gárate, J. I., Martínez de Alegría, I., & Ibarra, E. (2015). AC and DC technology in microgrids: A review. *Renewable and Sustainable Energy Reviews*, 43, 726–749. <https://doi.org/10.1016/j.rser.2014.11.067>

- Planas, E., Gil-De-Muro, A., Andreu, J., Kortabarria, I., & Martínez De Alegría, I. (2013). General aspects, hierarchical controls and droop methods in microgrids: A review. *Renewable and Sustainable Energy Reviews*, 17, 147–159. <https://doi.org/10.1016/j.rser.2012.09.032>
- Prevedello, G., & Werth, A. (2021). The benefits of sharing in off-grid microgrids: A case study in the Philippines. *Applied Energy*, 303(August), 117605. <https://doi.org/10.1016/j.apenergy.2021.117605>
- Proudlove, R., Finch, S., & Thomas, S. (2020). Factors influencing intention to invest in a community owned renewable energy initiative in Queensland, Australia. *Energy Policy*, 140(March), 111441. <https://doi.org/10.1016/j.enpol.2020.111441>
- Pullins, S. (2019). Why microgrids are becoming an important part of the energy infrastructure. *Electricity Journal*, 32(5), 17–21. <https://doi.org/10.1016/j.tej.2019.05.003>
- R. H. Lasseter. (2002). MicroGrids. *Proceeding of IEEE Power Engineering Society Winter Meeting*, 1, 305–308.
- Raman, G., & Peng, J. C.-H. (2018). Residential Microgrids for Increasing Community Acceptance of Smart Grid Services. *2018 IEEE/PES Transmission and Distribution Conference and Exposition (T&D)*, 1–9. <https://doi.org/10.1109/TDC.2018.8440247>
- Renewable Energy Agency, I. (2022). *China's route to carbon neutrality: Perspectives and the role of renewables*. [www.irena.org](http://www.irena.org)
- Rezkallah, M., Chandra, A., Singh, B., & Singh, S. (2019). Microgrid: Configurations, control and applications. *IEEE Transactions on Smart Grid*, 10(2), 1290–1302. <https://doi.org/10.1109/TSG.2017.2762349>
- Rioux-Gobeil, F., & Thomassin, A. (2024). A just energy transition for Indigenous peoples: From ideal deliberation to fairness in Canada and Australia. *Energy Research and Social Science*, 114. <https://doi.org/10.1016/j.erss.2024.103593>

- Rod Walton. (2024, June 26). *Europa Lag: Why Microgrid Adoption is Slower Across the Pond*. Microgrid Knowledge.
- Romankiewicz, J., Marnay, C., Zhou, N., & Qu, M. (2014). Lessons from international experience for China's microgrid demonstration program. *Energy Policy*, 67, 198–208. <https://doi.org/10.1016/j.enpol.2013.11.059>
- Romero-Rubio, C., & de Andrés Díaz, J. R. (2015). Sustainable energy communities: A study contrasting Spain and Germany. *Energy Policy*, 85, 397–409. <https://doi.org/10.1016/j.enpol.2015.06.012>
- Ruchi Soni. (2020). *Three key challenges to scale up the mini-grid sector*. SE for All. <https://www.seforall.org/news/three-key-challenges-to-scale-up-the-mini-grid-sector?>
- Ruggiero, S., Onkila, T., & Kuittinen, V. (2014). Realizing the social acceptance of community renewable energy: A process-outcome analysis of stakeholder influence. *Energy Research and Social Science*, 4(C), 53–63. <https://doi.org/10.1016/j.erss.2014.09.001>
- S. M. Kaviri, M. Pahlevani, P. Jain, & A. Bakhshai. (2017). A review of AC microgrid control methods. *IEEE 8th International Symposium on Power Electronics for Distributed Generation Systems (PEDG)*, 1–8. <https://doi.org/10.1109/PEDG.2017.7972498>.
- S. Pati, K. B. Mohanty, A. Choudhury, & S. Kar. (2017). Integration and power control of a micro-hydro-PV-wind based hybrid microgrid. *2017 International Conference on Circuit ,Power and Computing Technologies (ICCPCT)*, 1–6. <https://doi.org/10.1109/ICCPCT.2017.8074183>.
- Salehi, N., Martinez-Garcia, H., Velasco-Quesada, G., & Guerrero, J. M. (2022). A Comprehensive Review of Control Strategies and Optimization Methods for Individual and Community Microgrids. *IEEE Access*, 10, 15935–15955. <https://doi.org/10.1109/ACCESS.2022.3142810>

- Schönauer, A.-L., & Glanz, S. (2022). Hydrogen in future energy systems: Social acceptance of the technology and its large-scale infrastructure. *International Journal of Hydrogen Energy*, 47(24), 12251–12263. <https://doi.org/https://doi.org/10.1016/j.ijhydene.2021.05.160>
- Scovell, M., McCrea, R., Walton, A., & Poruschi, L. (2024). Local acceptance of solar farms: The impact of energy narratives. *Renewable and Sustainable Energy Reviews*, 189. <https://doi.org/10.1016/j.rser.2023.114029>
- Scovell, M., & Walton, A. (2024). Blue or Green? Exploring Australian acceptance and beliefs about hydrogen production methods. *Journal of Cleaner Production*, 444. <https://doi.org/10.1016/j.jclepro.2024.141151>
- Sechilariu, M., Locment, F., & Darene, N. (2018). Social Acceptance of Microgrids Dedicated to Electric Vehicle Charging Stations. *2018 7th International Conference on Renewable Energy Research and Applications (ICRERA)*, 1374–1379. <https://doi.org/10.1109/ICRERA.2018.8566787>
- Seyfang, G., Park, J. J., & Smith, A. (2013). A thousand flowers blooming? An examination of community energy in the UK. *Energy Policy*, 61, 977–989. <https://doi.org/10.1016/j.enpol.2013.06.030>
- Shah Danish, M. S., Senjyu, T., Funabashia, T., Ahmadi, M., Ibrahimi, A. M., Ohta, R., Rashid Howlader, H. O., Zaheb, H., Sabory, N. R., & Sediqi, M. M. (2019). A sustainable microgrid: A sustainability and management-oriented approach. *Energy Procedia*, 159, 160–167. <https://doi.org/10.1016/j.egypro.2018.12.045>
- Shahbazitabar, M., Abdi, H., Nourianfar, H., Anvari-Moghaddam, A., Mohammadi-Ivatloo, B., & Hatziargyriou, N. (2021). An introduction to microgrids, concepts, definition, and classifications. *Power Systems*, 3–16. [https://doi.org/10.1007/978-3-030-59750-4\\_1](https://doi.org/10.1007/978-3-030-59750-4_1)

- Shahidehpour, M., & Clair, J. F. (2012). A Functional Microgrid for Enhancing Reliability, Sustainability, and Energy Efficiency. *Electricity Journal*, 25(8), 21–28. <https://doi.org/10.1016/j.tej.2012.09.015>
- Shanmugavel, N., Alagappan, C., & Balakrishnan, J. (2022). Acceptance of electric vehicles: A dual-factor approach using social comparison theory and technology acceptance model. *Research in Transportation Business & Management*, 45, 100842. <https://doi.org/https://doi.org/10.1016/j.rtbm.2022.100842>
- Sharon J.W.Klein, & Stephanie Coffey. (2016). Building a sustainable energy future, one community at a time. *Renewable and Sustainable Energy Reviews*, 60, 867–880. <https://doi.org/https://doi.org/10.1016/j.rser.2016.01.129>
- Shove, E., & Walker, G. (n.d.). *What is energy for? Social practice and energy demand*.
- Soshinskaya, M., Crijns-Graus, W. H. J., Guerrero, J. M., & Vasquez, J. C. (2014). Microgrids: Experiences, barriers and success factors. In *Renewable and Sustainable Energy Reviews* (Vol. 40, pp. 659–672). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2014.07.198>
- Sousa T., Soares T., Pinson P., Baroche T., Sorin E., & Moret F. (2019). Peer-to-peer and community-based markets: A comprehensive review. *Renewable and Sustainable Energy Reviews*, 104, 367–378. <https://doi.org/10.1016/j.rser.2019.01.036>
- Stadler, M., Cardoso, G., Mashayekh, S., Forget, T., DeForest, N., Agarwal, A., & Schönbein, A. (2016). Value streams in microgrids: A literature review. *Applied Energy*, 162, 980–989. <https://doi.org/10.1016/j.apenergy.2015.10.081>
- Su, W., & Wang, J. (2012). Energy Management Systems in Microgrid Operations. *Electricity Journal*, 25(8), 45–60. <https://doi.org/10.1016/j.tej.2012.09.010>
- Syed, M. M., & Morrison, G. M. (2021). A rapid review on community connected microgrids. *Sustainability (Switzerland)*, 13(12). <https://doi.org/10.3390/su13126753>

- Tamasiga, P., Onyeaka, H., Altaghlibi, M., Bakwena, M., & houssin Ouassou, E. (2024). Empowering communities beyond wires: Renewable energy microgrids and the impacts on energy poverty and socio-economic outcomes. *Energy Reports*, 12, 4475–4488. <https://doi.org/https://doi.org/10.1016/j.egy.2024.10.026>
- Tao, L., Schwaegerl, C., Narayanan, S., & Zhang, J. H. (2011). From laboratory Microgrid to real markets Challenges and opportunities. *8th International Conference on Power Electronics - ECCE Asia: "Green World with Power Electronics", ICPE 2011-ECCE Asia*, 264–271. <https://doi.org/10.1109/ICPE.2011.5944600>
- Taufik, D., & Dagevos, H. (2021). Driving public acceptance (instead of skepticism) of technologies enabling bioenergy production: A corporate social responsibility perspective. *Journal of Cleaner Production*, 324, 129273. <https://doi.org/https://doi.org/10.1016/j.jclepro.2021.129273>
- Toke, D. (2005). Explaining wind power planning outcomes: Some findings from a study in England and Wales. *Energy Policy*, 33(12), 1527–1539. <https://doi.org/10.1016/j.enpol.2004.01.009>
- Uddin, M., Mo, H., Dong, D., & Elsayah, S. (2023). Techno-economic potential of multi-energy community microgrid: The perspective of Australia. *Renewable Energy*, 219. <https://doi.org/10.1016/j.renene.2023.119544>
- Ullah, S., Haidar, A. M. A., Hoole, P., Zen, H., & Ahfock, T. (2020). The current state of Distributed Renewable Generation, challenges of interconnection and opportunities for energy conversion based DC microgrids. *Journal of Cleaner Production*, 273, 122777. <https://doi.org/10.1016/j.jclepro.2020.122777>
- Unamuno, E., & Barrena, J. A. (2015). Hybrid ac/dc microgrids - Part I: Review and classification of topologies. *Renewable and Sustainable Energy Reviews*, 52, 1251–1259. <https://doi.org/10.1016/j.rser.2015.07.194>

- Urmee, T., Thoo, S., & Killick, W. (2012). Energy efficiency status of the community housing in Australia. In *Renewable and Sustainable Energy Reviews* (Vol. 16, Issue 4, pp. 1916–1925). <https://doi.org/10.1016/j.rser.2012.01.034>
- Ustun, T. S., Ozansoy, C., & Zayegh, A. (2011). Recent developments in microgrids and example cases around the world - A review. *Renewable and Sustainable Energy Reviews*, 15(8), 4030–4041. <https://doi.org/10.1016/j.rser.2011.07.033>
- Valencia, F., Billi, M., & Urquiza, A. (2021). Overcoming energy poverty through micro-grids: An integrated framework for resilient, participatory sociotechnical transitions. *Energy Research and Social Science*, 75(August 2020), 102030. <https://doi.org/10.1016/j.erss.2021.102030>
- van der Schoor, T., & Scholtens, B. (2019). The power of friends and neighbors: a review of community energy research. In *Current Opinion in Environmental Sustainability* (Vol. 39, pp. 71–80). Elsevier B.V. <https://doi.org/10.1016/j.cosust.2019.08.004>
- Vanadzina, E., Mendes, G., Honkapuro, S., Pinomaa, A., & Melkas, H. (2019). Business models for community microgrids. *International Conference on the European Energy Market, EEM, 2019-Septe*. <https://doi.org/10.1109/EEM.2019.8916368>
- Walker, G. (2007). End of Award Report to the Economic and Social Research Council Community Energy Initiatives: Embedding Sustainable Technology at a Local Level Funded under the Sustainable Technologies Programme. *Energy*.
- Walker, G. (2008). What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy*, 36(12), 4401–4405. <https://doi.org/10.1016/j.enpol.2008.09.032>
- Walker, G. (2011). The role of “community” in carbon governance. *WIREs Climate Change*. <https://doi.org/https://doi.org/10.1002/wcc.137>

- Walker G, & Cass N. (2007). Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. *Area*, 39, 458–469.
- Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy*, 36(2), 497–500. <https://doi.org/10.1016/j.enpol.2007.10.019>
- Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663. <https://doi.org/10.1016/j.enpol.2009.05.055>
- Walker, G., Hunter, S., Devine-Wright, P., Evans, B., & Fay, H. (2007). Harnessing community energies: Explaining and evaluating community-based localism in renewable energy policy in the UK. *Global Environmental Politics*, 7(2), 64–82. <http://www.mitpressjournals.org/doi/pdf/10.1162/glep.2007.7.2.64>
- Walker, G., & Simcock, N. (2012). Community energy systems. In *International Encyclopedia of Housing and Home* (Vol. 1). Elsevier Ltd. <https://doi.org/10.1016/B978-0-08-047163-1.00598-1>
- Wang, C., Yan, J., Marnay, C., Djilali, N., Dahlquist, E., Wu, J., & Jia, H. (2018). Distributed Energy and Microgrids (DEM). *Applied Energy*, 210, 685–689. <https://doi.org/10.1016/j.apenergy.2017.11.059>
- Wang, Y., Rousis, A. O., & Strbac, G. (2020). On microgrids and resilience: A comprehensive review on modeling and operational strategies. *Renewable and Sustainable Energy Reviews*, 134(September), 110313. <https://doi.org/10.1016/j.rser.2020.110313>
- Warneryd, M., Håkansson, M., & Karltorp, K. (2020). Unpacking the complexity of community microgrids: A review of institutions' roles for development of microgrids. *Renewable and Sustainable Energy Reviews*, 121(December 2019). <https://doi.org/10.1016/j.rser.2019.109690>

- Warneryd, M., & Karltorp, K. (2022). Microgrid communities: disclosing the path to future system-active communities. *Sustainable Futures*, 4(January), 100079. <https://doi.org/10.1016/j.sftr.2022.100079>
- Wei, P., & Chen, W. (2019). Microgrid in China: A review in the perspective of application. *Energy Procedia*, 158, 6601–6606. <https://doi.org/10.1016/j.egypro.2019.01.059>
- Wolsink, M. (2018). Social acceptance revisited: gaps, questionable trends, and an auspicious perspective. In *Energy Research and Social Science* (Vol. 46, pp. 287–295). Elsevier Ltd. <https://doi.org/10.1016/j.erss.2018.07.034>
- Wolsink, M. (2020). Distributed energy systems as common goods: Socio-political acceptance of renewables in intelligent microgrids. *Renewable and Sustainable Energy Reviews*, 127(March), 109841. <https://doi.org/10.1016/j.rser.2020.109841>
- Wood Mackenzie. (2024, April). *Market Report US microgrid outlook 2024*.
- Wouters, C. (2015). Towards a regulatory framework for microgrids - The Singapore experience. *Sustainable Cities and Society*, 15, 22–32. <https://doi.org/10.1016/j.scs.2014.10.007>
- Wright, S., Frost, M., Wong, A., & Parton, K. (2024). Australian microgrids: Navigating complexity in the regional energy transition. *Energy Research and Social Science*, 113. <https://doi.org/10.1016/j.erss.2024.103540>
- Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683–2691. <https://doi.org/10.1016/j.enpol.2006.12.001>
- Yamashita, D. Y., Vechiu, I., & Gaubert, J. P. (2020). A review of hierarchical control for building microgrids. *Renewable and Sustainable Energy Reviews*, 118(November 2019), 109523. <https://doi.org/10.1016/j.rser.2019.109523>

- Yu, J., Marnay, C., Jin, M., Yao, C., Liu, X., & Feng, W. (2018). Review of Microgrid Development in the United States and China and Lessons Learned for China. *Energy Procedia*, 145, 217–222. <https://doi.org/10.1016/j.egypro.2018.04.038>
- Zhou, Y., Panteli, M., Moreno, R., & Mancarella, P. (2018). System-level assessment of reliability and resilience provision from microgrids. *Applied Energy*, 230(April), 374–392. <https://doi.org/10.1016/j.apenergy.2018.08.054>
- Zia M.F., Benbouzid M, Elbouchikhi E., Muyeen S.M., Techato K., & Guerrero J.M. (2020). Microgrid transactive energy: Review, architectures, distributed ledger technologies, and market analysis. *IEEE Access*, 8, 19410–19432. <https://doi.org/10.1109/ACCESS.2020.2968402>

# Chapter 3: Research Design and Methodology



*Coober Pedy in remote South Australia has a hybrid microgrid powered by solar and wind, backed up with battery power and diesel. Retrieved from <https://arena.gov.au/blog/microgrids-cheaper-cleaner-reliable-energy-for-remote-communities/> on 25/09/2024*

“What we call the world is a product of some mind”

(Jerome Bruner, 1987)

## Chapter 3. Research Design and Methodology

### 3.1 Introduction

This chapter outlines the methodological approach employed in this thesis to investigate the social dimensions of microgrids within the broader context of Australia's energy transition, with a particular emphasis on the role of local communities in rural and remote areas. It describes the philosophical assumptions, theoretical framework, and methodological strategies that underpin this research.

As highlighted in the literature review (Chapter 2), there is a significant gap in research exploring the importance of community engagement in microgrid development and implementation. To address this gap, this research employs a qualitative methodological approach, drawing on data from real-world microgrid projects in rural and remote communities across Australia. This chapter provides a detailed account of the methodological choices and justifications that guided this investigation, offering a holistic and integrated perspective on the methodological underpinnings of this thesis. While Chapters 4, 5, and 6, which comprise published academic articles, may include some discussion of the methodology, this chapter provides a more comprehensive and synthesised analysis of the chosen approach and its rationale.

This chapter is divided into seven sections. Following this introduction, section 3.2 explores the researcher's philosophical views, focusing on the philosophical considerations, such as ontological and epistemological orientations and the author's worldview, that inform the research design and research methodologies. Section 3.3 provides the theoretical framework underpinning the study for examining the role of social aspects of microgrids in energy transition in Australia. Section 3.4 presents the research design, including a justification for the qualitative approach and analysis of the strategies of inquiry for data collection. Section 3.5 discusses the research methods

within the selected methodology, providing tools for a comprehensive understanding of the social aspects of microgrids. Section 3.6 outlines the procedures for data analysis, including thematic analysis and coding strategies used to interpret the data. The chapter concludes with a summary in Section 3.7, highlighting the key points of the methodology section, along with major limitations and challenges. The overarching structure of the research design has been demonstrated in Figure 10, the details of which will be provided in subsequent sections.



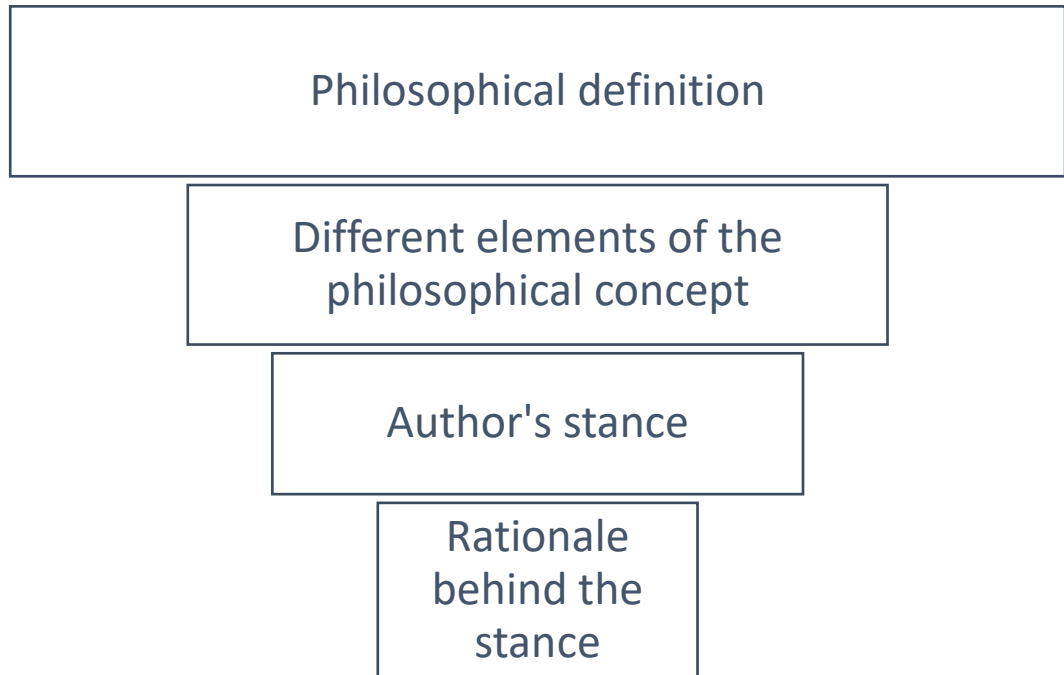
*Figure 10 Components of Research Design*

As stated in Figure 10, ontology deals with the nature of reality and existence, defining what constitutes reality and knowledge. Epistemology is concerned with the nature of knowledge and how it is acquired. Worldview refers to the overall perspective through which the world is viewed, encompassing beliefs, values, and assumptions about reality. Theoretical considerations involve selecting relevant theories and frameworks to guide research and interpret data. Research methodology refers to the overall approach and strategy used to conduct research. Research methods are the specific tools and

techniques used to collect and analyse data. This comprehensive research design ensures a robust and transparent methodological foundation for investigating the social dimensions of microgrids in Australia.

### 3.2: Philosophical considerations – Positioning of the researcher

This section outlines the author's stance on key philosophical concepts, including ontology, epistemology, and worldview, providing insight into the philosophical considerations that have guided this research. Philosophical considerations play a crucial role in designing the research approach and processes, influencing both the selection of methodologies and the strategies for data collection and analysis (Creswell, 1994). The researcher's perspective and underlying philosophical framework contribute to a deeper understanding of concepts within the social sciences (Guba, 1990). Reflecting on these assumptions also justifies the methodological choices employed in this thesis. Each sub-section begins with a definition of the concept and an exploration of its key elements, followed by the author's stance and a justification for choosing this stance. The framework for organising philosophical considerations is presented in Figure 11, providing a structured approach to understanding their role in this research.



*Figure 11 Structural Framework of Framing Philosophical Considerations*

### 3.2.1 Ontological considerations

#### 3.2.1.1 Ontology definition

In philosophical terms, ontology refers to a researcher's belief regarding the nature of the social world, exploring fundamental questions about what is real and what exists (Johnson & R. Gray, 2010). As explained by Moon and Black (2014), ontological inquiries further examine fundamental questions, such as what it means for something to exist and whether reality is inherently objective or shaped by individual perceptions and thoughts (Moon & Blackman, 2014). The following paragraphs offer a comprehensive overview of different ontological views employed in social science literature, reflecting on my role as a researcher and the ontological considerations that guided this research. Figure 12 highlights the key elements of ontological considerations.

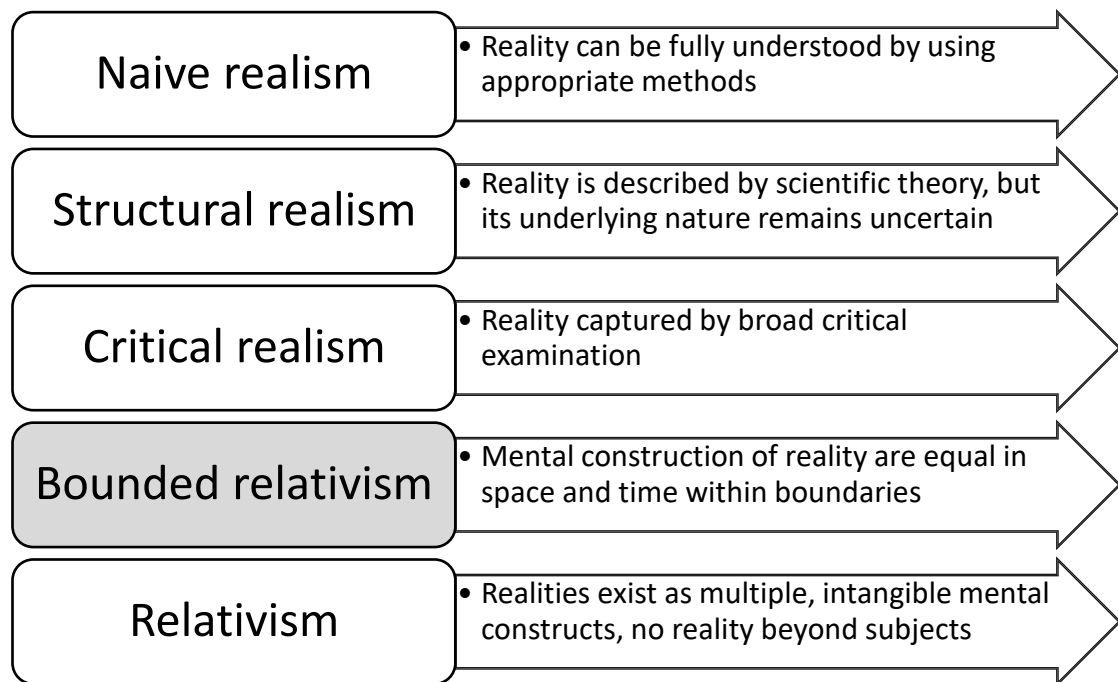


Figure 12 Key elements of Ontology – Adopted from (Moon & Blackman, 2014)

### 3.2.1.2 Ontology - Key Elements and Considerations

Moon et al. (2014) have divided the ontological considerations into two viewpoints, i.e., realism and relativism. The realists argue that only one reality exists, which can be understood, studied, and experienced, and that this reality is independent of human experiences and behaviours (Moon & Blackman, 2014).

On the other hand, relativists argue that reality is shaped by human perception, which means that there is no single, objective reality; rather, reality is subjective and varies for each individual based on their experiences in a specific time and context (Johnson & R. Gray, 2010). Within the context of relativism, bounded relativism argues that the shared reality exists in a bounded group, which is shaped by the morals, culture and perception of the people living in the group (Tashakkori & C. Teddlie, 2010). On the other hand, the relativist approach states that each person constructs their own reality in their mind. These realities are considered fluid as they are historically and culturally affected interpretations rather than eternal truths of some kind. At different times and places, there have been very divergent interpretations of the same phenomena (Crotty, 1998:64).

### 3.2.1.3 Researcher's ontological position

Given this study's focus on understanding the role of local communities in microgrid projects and the factors influencing social acceptance, I adopted a bounded relativism ontological perspective. The rationale for this choice is explained by the following points:

1. Since the research examines microgrids' role in the energy transition, specifically, the drivers, barriers, and opportunities across different Australian communities, it requires exploring diverse stakeholder perspectives, each of which shapes its own reality. Bounded relativism acknowledges that reality is subjective and that multiple realities exist within certain boundaries, reflecting the variations among communities and individuals.
2. Similarly, understanding community engagement strategies and the factors impacting social acceptance of microgrids requires examining the perceptions of multiple stakeholders, a viewpoint aligned with a bounded relativist ontology. Given that each community differs and community engagement practices vary considerably, a one-size-fits-all solution is inapplicable across all communities and projects. This requires collating multiple perceptions around microgrids and recognising the existence of multiple realities.

While a relativist viewpoint, suggesting that individuals construct their own realities, was initially considered for this research design, such granularity lies beyond the scope of this thesis. Instead, this research focuses on the collective realities constructed by local communities, acknowledging the inherent diversity and potential fragmentations within these communities. Therefore, this thesis adopts a bounded relativist ontological perspective.

## 3.2.2 Epistemology

### 3.2.2.1 Epistemology definition

In philosophical terms, epistemology deals with the question of how knowledge is generated and how to validate existing knowledge. The epistemological assumptions also look at the validity of different ways in which knowledge has been acquired (Moon & Blackman, 2014). The way researchers answer the question about how the knowledge is obtained and how it can be validated has a significant impact on the research methods and research analysis (Crotty, 1998). To illustrate different epistemological positions, Crotty (1998) proposed a continuum that was analysed in this study, highlighting the relationship between the subject and the object (Crotty, 1998), which has been analysed in section 3.2.2.2.

### 3.2.2.2 Epistemology: Key Elements and Considerations

Objectivism states that knowledge, truth and meaning exist independently of the observer, and the truth lies in the objects that are being studied (Moon & Blackman, 2014). Researchers with an objectivist view detach themselves from the subject under consideration, ensuring that their own interests, values, or interpretations do not influence the production of knowledge (Simon Frankel Pratt et al., 2022).

Furthermore, subjectivism posits that knowledge and truth are context-dependent and plural (Thomas A Schwandt, 2000). The proponent of this philosophical belief argues that there is no fixed meaning or reality, and the subject's perceptions shape the reality of the object under investigation (Jerome Bruner, 1987). The significance of subjectivist research lies in uncovering how personal experiences influence an individual's perception of the world as individuals assign meaning and value to the world, interpreting it in ways that are meaningful to them (Crotty, 1998; Simon Frankel Pratt et al., 2022). While objectivism adheres to the principle "seeing is believing," subjectivism is summarised as "believing determines what is seen" (Pratt, 1998).

Constructivist epistemology takes a position that lies between subjectivism and objectivism, stating that truth is created through interactions with the realities of the world. There is no pre-existing, independent reality, and the world is a product of human minds (Jerome Bruner, 1987). This epistemological stance posits that individuals interpret the same object or phenomenon in unique ways, influenced by their cultural, historical, and social context, and meanings emerge through interaction with the world (Creswell, 2017; Crotty, 1998).

Other epistemological positions also exist, such as positivism, pluralism and integral epistemology (Bryman, 2012; Creswell, 2023; Crotty, 1998). However, these are not discussed in detail as they are less relevant to the scope of this thesis.

### 3.2.2.3 Researcher's epistemological position

Informed by the preceding discussion of epistemological concepts, this thesis adopts a constructivist epistemological approach. Constructivism posits that reality is socially constructed through interactions and shared understandings. This aligns with the research's emphasis on understanding microgrid adoption, perception, and community engagement through direct interaction with local communities and stakeholders involved in these projects. Furthermore, this constructivist epistemology is intrinsically linked to a relativist ontology, which asserts the existence of multiple realities and emphasises the importance of human interaction in comprehending these diverse perspectives. Recognising the diverse meanings and interpretations of microgrids, constructivism informs the research design by focusing on the necessity of engaging with local stakeholders, thereby uncovering multiple realities and assigning meaning to the phenomena under investigation.

### 3.2.3 Worldview

#### 3.2.3.1 Worldview definition

A worldview is a broad, shared narrative representing researchers' views to interpret their experiences and understand the world (Crotty, 1998). The worldview perspective outlines the researcher's general philosophical outlook of the world and how this outlook guides the nature of research (Bryman, 2012). Worldview also includes the researcher's underlying beliefs about reality (ontology), knowledge (epistemology), and guiding theories, shaping how they approach and conduct their studies (Creswell, 1994). This thesis adapts one of Creswell's four worldviews—postpositivist, constructivist, transformative, and pragmatic—to guide the research approach. The following paragraphs provide a brief overview of these worldviews, followed by the researcher's perspective.

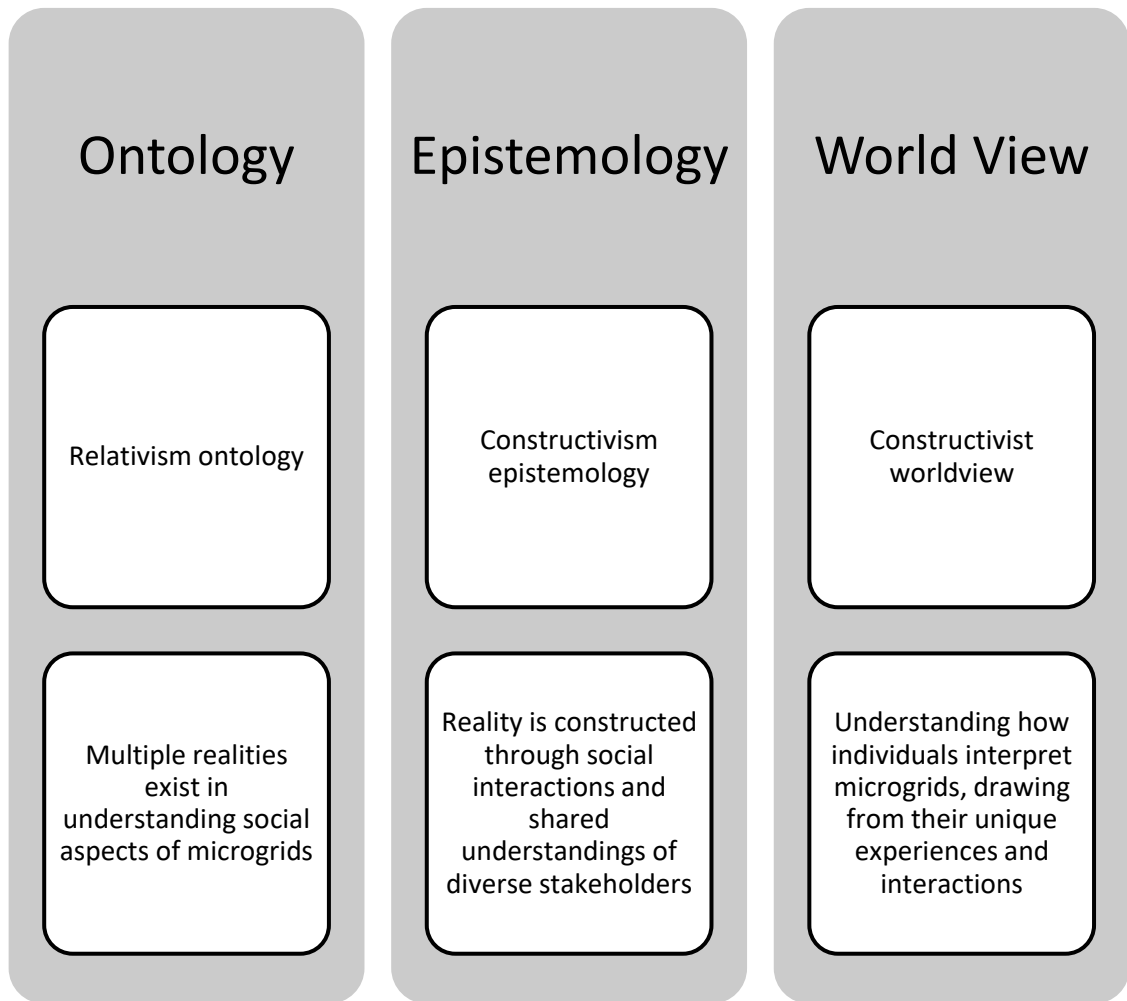
#### 3.2.3.2 Worldview: Key Elements and Considerations

The postpositivist worldview aligns with the traditional scientific method, where researchers aim to determine cause and effect through empirical observation and measurement (Bryman, 2012). Researchers with a constructivist worldview seek to understand the world they live in by constructing subjective meanings directed toward objects or phenomena. Constructivist research aims to uncover and interpret these meanings, often using qualitative research methods (Jerome Bruner, 1987; Thomas A Schwandt, 2000). A transformative worldview asserts that research must be intertwined with political agendas to address social oppression at various levels (Creswell, 2023). Lastly, a pragmatic worldview focuses on "what works" in the research (Bryman, 2012). The followers of this concept are not committed to a single philosophical or methodological perspective but instead respond to challenges by using a variety of approaches to understand the problem and devise solutions.

Other worldviews explored by social scientists include participatory, decolonial, Indigenous, southern, transdisciplinary, interpretive, phenomenological, critical, feminist, and postmodern perspectives (Bryman, 2012). However, this thesis does not elaborate on these perspectives, as they are less relevant to the scope of this study.

#### 3.2.3.3 Researcher's worldview

In this thesis, I adopt a constructivist worldview to guide the research design, given the focus of this thesis on understanding how Australian stakeholders interpret microgrids based on their unique experiences and interactions. Specifically, this research explores how diverse stakeholders involved in microgrid projects define key drivers, identify associated barriers, and determine best practices for community engagement regarding microgrid adoption. Collecting this data requires interacting with local communities, project managers, retailers, engineers, and local government officials to fully understand the aforementioned aspects of microgrid adoption. Since a constructivist worldview states that reality is understood through active engagement with subjects, this worldview underpins the methodological choices for data collection. The perceptions of stakeholders are central to comprehending the complex social dimensions of microgrid projects, making a constructivist worldview particularly well-suited for this study. Figure 13 summarises the philosophical underpinning guiding the research design. The details of the methods employed for the data collection are mentioned in section 3.4.



*Figure 13 Summary of Philosophical Considerations*

### 3.3 Theoretical framework – Multi-Level Perspective

Defining a theoretical framework for the research is essential for guiding the research process as it acts as a philosophical foundation that informs the methodology, offering a contextual setting for the entire research process (Crotty, 1998). Establishing a theoretical framework allows the researcher to select the right data collection methodology in response to the defined research questions. The theoretical framework also provides a coherent lens through which the study is conducted, ensuring that each component aligns with our underlying philosophical stance (Creswell, 2023). The following section explores the theoretical framework employed in this research,

examining how it informs the methodological choices and enhances a comprehensive understanding of the topic.

### 3.3.1 Environmental Sustainability Transitions

Transitions are defined as deep social change characterised by shifts in structure (e.g., infrastructure, institutions, markets), culture (e.g., values, worldviews), and practices (e.g., norms, routines) (Loorbach & Rotmans, 2010). In socio-technical systems, sustainability transitions involve fundamental changes in the relationship between social and technical elements, entailing the co-evolution of technology, regulation, user practices, markets, cultural meaning, infrastructure, and supply networks (Geels, 2011; Köhler et al., 2019). Changes within one dimension can trigger shifts across other elements, suggesting a dynamic interplay that sustains or disrupts stability at various levels (Geels, 2002).

Sustainability transitions are characterised by a multi-dimensional and co-evolutionary process that involves complex interactions between technological, institutional, social, and cultural elements (Köhler et al., 2019). These transitions cannot be understood through a single theoretical lens, as they are shaped by the agency of diverse actors, including academia, policymakers, industry representatives, civil society, and households. Each of these groups brings its own goals and perspectives, leading to a non-linear progression that unfolds over extended periods, often spanning decades (Köhler et al., 2019). According to Geels (2011), sustainability transitions have distinctive features that set them apart from many historical transitions (Geels, 2011). While past transformations often emerged from entrepreneurs capitalising on new technologies, sustainability transitions are deliberately “goal-oriented”, focusing on persistent environmental challenges (Smith et al., 2005). The role of public authorities and civil society is vital in promoting collective action and enhancing the shift towards sustainable social-technical systems (Elzen et al., 2011). Besides, sustainability transitions do not

consistently deliver clear user benefits, as they typically address collective rather than personal needs (Geels, 2011). In many cases, sustainable solutions fall short when compared to established technologies in terms of cost and performance. Thus, it is unlikely that these transitions will replace existing systems without changes in economic frameworks, policy reforms, and political processes. Sustainability transitions typically involve changes in the transport, energy, and agri-food sectors, and while large incumbent firms may not initially advocate for these transitions, their involvement plays a crucial role in fostering environmental innovations by providing valuable resources and complementary assets. These characteristics highlight the inherent multidimensional nature of sustainability transitions, which encompass interactions among technology, policy and power, economics and markets, and cultural discourses.

### 3.3.2 Multi-Level Perspective (MLP)

This thesis adopts the sustainability transition framework, the Multi-Level Perspective (MLP), as a theoretical lens to examine the social dimensions of microgrids and their role in facilitating Australia's energy transition. The concept was first noted in a book chapter by Arie Rip & René Kemp, which explored change in sociotechnical systems and introduced the concepts of regimes and landscapes (Arie Rip & René Kemp, 1998). This inspired Frank Geels, who developed the Multi-Level Perspective (MLP) in 2002, establishing it as a foundational theoretical framework in the emerging field of sustainability transitions. Geels illustrated the applicability of this framework by analysing historical transitions in water and sanitation, transport, and energy systems in the Netherlands (Geels, 2002).

#### 3.3.2.1 Key elements of MLP

The multi-level perspective (MLP) is a middle-range theory that conceptualises dynamic patterns in socio-technical transitions (Geels, 2011). MLP is a valuable integrative framework, connecting insights from technology studies, evolutionary economics,

structuration theory, neo-institutional theory, sociology, and sustainability transition literature to provide a holistic view of socio-technical change (Geels, 2002; Geels & Schot, 2007). While other frameworks tend to focus on the technical attributes of the technology, MLP is distinct in its capacity to explain how broader societal, regulatory, and environmental factors can support or hinder energy transitions. This multi-layered framework is highly applicable to the energy transition research, as it enables the examination of how the emergence of innovations contributes to broader shifts in political, economic, and social structures driven by climate objectives, resilience demands, and evolving energy market dynamics (Berkeley et al., 2017).

The Multi-Level Perspective (MLP) outlines that socio-technical transitions occur in four stages (Geels et al., 2017). In the first phase, innovative technologies and concepts emerge within protected niches, where they remain experimental and unstable. The second phase sees these innovations entering small market niches, which provide resources for further development, specialisation, and the emergence of a dominant design. In this phase, the technology continues to evolve and begins to stabilise. In the third phase, the innovation begins competing with the existing regime, aided by internal improvements and external pressures that create opportunities for adoption. Finally, in the fourth phase, innovative technology replaces the old system, leading to widespread adoption, institutionalisation, and structural adjustments in policies, infrastructure, and societal norms. This coordinated process enables innovations to transition from protected niches to mainstream markets, where they compete with established systems, driving a socio-technical transition that takes decades to unfold (Geels et al., 2017). MLP has further categorised the socio-technical transition into three levels which are defined by Geels as niche innovations (emerging trends), socio-technical regimes (established systems), and the socio-technical landscape (macro-level societal influences) that interact to drive systemic change (Arie Rip & René Kemp, 1998; Geels, 2002; Geels &

Schot, 2007). An explanation of the three layers of the framework has been provided in the upcoming paragraphs.

### **Socio-technical landscape**

The socio-technical landscape represents broader macro-level influences, such as economic trends, cultural shifts, large-scale political developments, and ecological pressures which create pressures on both regimes and niches (Arie Rip & René Kemp, 1998; Geels, 2002; Sovacool BK., 2010). Changes at this level are typically slow-moving and difficult to influence directly, yet they exert a powerful force on the trajectory of technological adoption. For instance, landscape pressures, such as the advocacy for climate action policies, regulatory reforms, and international sustainability mandates, play a significant role in driving innovative, decentralised energy solutions (Rotmans & Loorbach, 2009).

### **Socio-technical regimes**

The socio-technical regime, as defined by Geels, as a meso-level stage, represents the existing socio-technical structure maintained by entrenched norms, regulatory frameworks, and established energy practices (Geels, 2002). This stage involves a broader array of actors, such as policymakers, consumers, and interest groups, whose interactions create stable development paths (Nelson & Winter, 1982). This stability emerges through standardised routines, regulations, policies, established infrastructures, and investments in expertise (Genus & Coles, 2008; Unruh GC, 2000). In the MLP framework, the regime represents dominant systems that resist radical innovations, as replacing existing systems requires systemic changes in regulations, policies, economic models, and user practices.

### **Niche innovations**

Niches, also called micro-levels, represent protected spaces where breakthrough innovations first emerge and new technologies and social practices begin as small, experimental configurations (Geels, 2002). These niche innovations are often unstable

and tend to underperform compared to mainstream alternatives, requiring “protected spaces” to develop outside market pressures. Niche networks, comprising enthusiastic innovators, researchers, and policymakers, play a crucial role in fostering early-stage innovations within protected environments despite challenges (Geels & Schot, 2007). Over time, when niche innovations align with broader landscape pressures such as policy changes, cultural shifts, or economic trends, they can disrupt the established regime and drive system-wide transformations. Figure 14 illustrates the multi-level perspective (MLP) on sociotechnical transitions, emphasising the interplay between technological niches, socio-technical regimes, and macro-level landscapes.

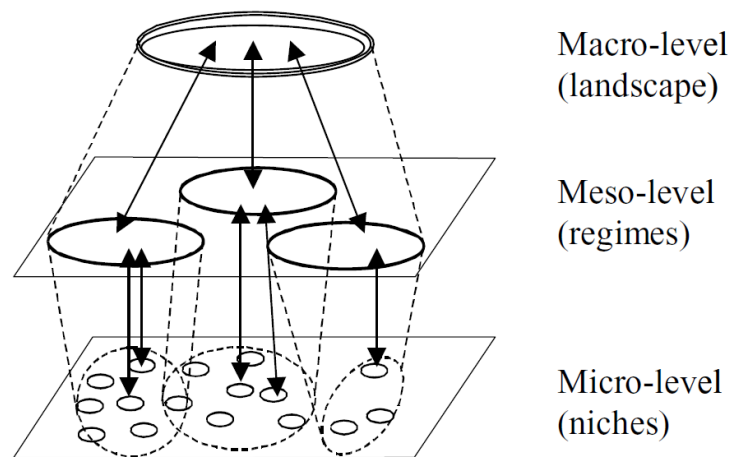


Figure 14 The multi-level concept in transition theory (source: Geels and Kemp 2000)

### 3.3.3 Applying the Multi-Level Perspective (MLP) to Microgrid Analysis in Australia

Microgrids in Australia currently operate within niche spaces due to their limited deployment and the technical, financial, regulatory, and social challenges they face. Government grants (discussed in Chapter 1) primarily support microgrid development through feasibility studies and pilot projects in rural and remote communities. These initiatives create 'protected spaces' where microgrid innovations can be tested and refined without immediate market pressures. Within these spaces, efforts focus on addressing technical challenges, developing cost-effective business models, and

fostering community support. However, microgrids remain largely disconnected from mainstream adoption, as they still face challenges necessary for integration into Australia's centralised energy regime. For microgrids to transition from niche innovations to mainstream solutions, they must overcome multiple regime-level barriers. Increasing landscape pressures, such as climate change and evolving global climate policies, are pressuring Australia's energy regime to accommodate decentralised energy solutions. While the existing regime remains structured around large-scale fossil fuel-based systems, decentralised renewable solutions, including microgrids, are emerging in response to these pressures. As renewable microgrids mature within niches, they will increasingly interact with the socio-technical regime, either aligning with existing structures or challenging dominant paradigms.

Given the research's focus on the social dimensions of microgrids, the MLP framework provides a valuable lens to identify the social and community-driven challenges that must be addressed to integrate microgrids into the existing energy regime. By exploring microgrid innovations within niche spaces, the thesis will highlight key social aspects, including community engagement, social acceptance, and the conflicts and barriers that hinder widespread adoption. Understanding these dynamics is crucial for facilitating the transition of microgrids from feasibility studies to mainstream energy solutions, especially for rural and remote communities. As Australia moves toward a more sustainable energy future, microgrids, through the support of engaged communities and responsive policies, could play a pivotal role in realising a resilient and decentralised energy landscape.

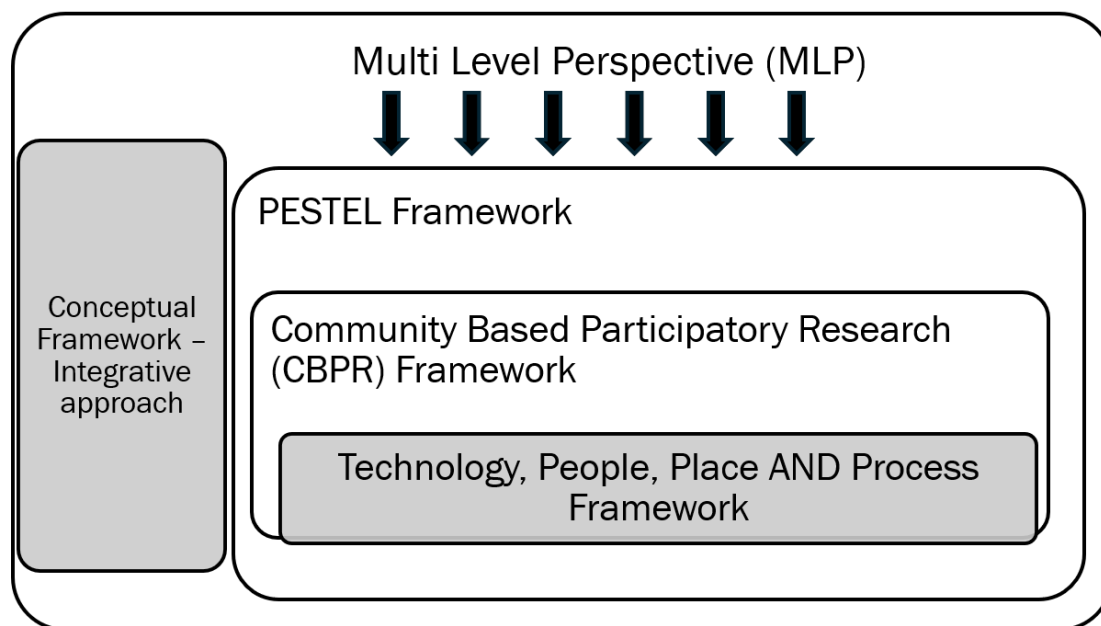
### 3.4 Conceptual Framework – Integrative approach

Developing a clear conceptual framework is critical for guiding both the theoretical underpinnings and empirical direction of this research (Maxwell, 2013; Ravitch & Riggan, 2016). In the context of sustainability transitions, a well-defined framework offers a systematic way to analyse the complex interplay among technological innovations, policy

interventions, market dynamics, and social practice. The conceptual framework of this thesis is constructed using an integrative approach.

This integrative approach was selected as it combines established theoretical frameworks and analytical models to undertake a holistic examination of the social dimensions relating to microgrid deployment in Australia. Using this approach allows for greater flexibility in applying different frameworks and methodologies, given the dynamic, complex, and nascent nature of the subject matter. It also helps capture the complex social realities of the individual and community attitudes, behaviour, and relationships, which are challenging to understand and explain by a single method.

As illustrated in Figure 15, the conceptual framework maps the interconnections between various theoretical frameworks and aligns them with the core research questions. The overarching theoretical lens employed in this study is the Multi-Level Perspective (MLP), which, as discussed in the previous section, provides a comprehensive framework for analysing socio-technical transitions by examining the interactions between niche innovations, regimes, and landscapes (Geels, 2002). In addition to MLP, this thesis integrates the Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) framework (which originated as a form of strategic planning in the 1960s for assessing the external factors that impact on businesses), the Community-Based Participatory Research (CBPR) framework (developed originally in the 1940s for action research and then adopted more widely in health), and the Technology, People, Place, and Process framework (developed in the 1960s for creating organisational change) to address the multiple and interconnected research questions. The integration of these frameworks within the conceptual framework allows for a systematic and multidimensional approach to exploring the social aspects pertaining to microgrid adoption



*Figure 15 Conceptual Framework: Integrative Approach*

Chapters 4, 5, and 6 provide a detailed discussion of the individual frameworks that constitute the conceptual framework. However, a brief introduction to these frameworks is presented here.

### 3.4.1 PESTEL Framework

The PESTEL framework is widely recognised for its ability to analyse external environmental factors, offering insights into both threats and opportunities (Perera, 2017). Originally developed for situational business analysis, the framework organises macro-level influences into six categories: Political, Economic, Social, Technological, Environmental, and Legal (Dwyer & Tanner, 2002; Yüksel, 2012). By providing a structured lens, PESTEL helps organisations refine their strategies, adapt operations, and set targets based on a clear understanding of the broader context in which they operate. In this research, PESTEL is an effective tool for categorising the barriers that emerged from Australian microgrid feasibility studies. The framework comprehensively examines the political, economic, social, technological, environmental, and legal factors influencing microgrid adoption in Australian communities. The findings will critically

assess the key barriers that must be addressed to facilitate the integration of microgrids into the existing energy regime. Further details on the application of the PESTEL framework are presented in Chapter 4.

### 3.4.2 Community-Based Participatory Research Framework

Community-based participatory Research (CBPR) provides a valuable framework for advancing research by prioritising and elevating the voices of historically and currently marginalised communities (B.A. Israel et al., 1998). It fosters a collaborative research process, bringing together researchers and community members to jointly conduct a systematic inquiry, with the goal of strengthening both research outcomes and community capacity for scientific engagement and advocacy (Davis, 2007).

In the sustainability transition literature, the CBPR framework offers a novel lens for analysing and assessing community engagement strategies within emerging technological domains, making it particularly relevant for studies that seek to involve stakeholders throughout the research process (Israel, 2019). By employing a collaborative inquiry approach, CBPR reframes community members as co-researchers rather than passive subjects, actively challenging traditional power imbalances, amplifying historically marginalised voices, and promoting collective ownership of the research process (Cannon et al., 2023). Originally applied in health and social contexts, CBPR has proven effective in shaping community engagement initiatives and building local capacity for both science and advocacy (Braithwaite, R. et al., 2007; Gavin J. Williams, 2013). Its emphasis on co-learning and mutual respect helps balance the pursuit of research goals with concrete, community-led action (B.A. Israel et al., 2013). Given these strengths, adopting a CBPR as a part of the conceptual framework allows for a richer understanding of community engagement strategies within diverse microgrid feasibility projects.

### 3.4.3 Technology, People, Place and Process Framework

The Technology, People, Place, and Process (TPPP) framework, adapted from Harold Leavitt's People Process Technology framework and proposed by Boudet (2019), is a conceptual framework used to provide a more holistic lens for understanding the factors shaping perceptions and acceptance of new energy technologies (Boudet, 2019).

The TPPP framework breaks down the adoption and perception of new renewable energy technologies into four core dimensions. The technology dimension refers to the objective analysis of risks and benefits that communities weigh before embracing new solutions, emphasising factors such as economic, environmental, and social impacts (Boudet, 2019). The people dimension focuses on sociodemographic attributes and social dynamics, which can significantly affect individual and collective perceptions. The place dimension highlights the importance of local context, including physical infrastructure, cultural heritage, and community-specific economic needs, all of which influence the acceptance of new technology. Lastly, the process dimension underscores how community engagement strategies are critical in garnering community support (Muttaqee et al., 2023). By integrating these dimensions, the TPPP framework comprehensively captures the diverse factors that shape how communities perceive and respond to emerging energy technologies like microgrids.

As shown in Figure 16, these frameworks collectively inform both the scope of inquiry and the methodological choices. By offering a holistic lens, the conceptual framework clarifies the core issues, shapes the research design, and ultimately ensures a comprehensive approach to investigating the research questions.

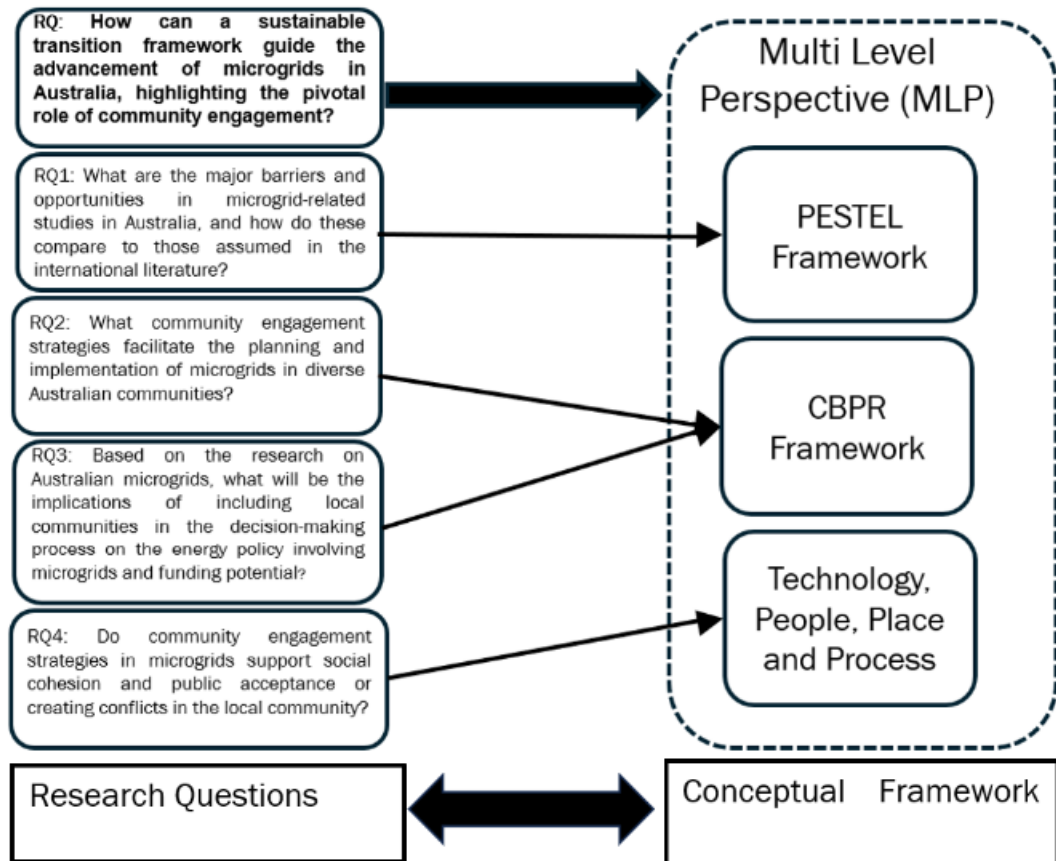


Figure 16 Relationship between the conceptual framework and the research questions

### 3.5 Research Design

The research design for this thesis comprises a qualitative research methodology, following a ground theory and case study approach and using mixed methods to investigate the social aspects relating to microgrids for rural and remote Australian communities. The following sections present a detailed description of the research design.

#### 3.5.1 Qualitative Research Methodology

Establishing a robust research methodology is an important part of the research design, as the methodology provides a structured pathway to effectively address the research questions and objectives (Creswell, 2023). Creswell (1994) defines research methodology as the study of research methods, encompassing the plans and procedures that guide research, ranging from broad theoretical assumptions to specific techniques

for data collection, analysis, and interpretation. This comprehensive plan is not just a sequence of steps but a reflection of the underlying philosophical assumptions that shape the direction of the research (Creswell, 1994).

There are three primary categories of research methodology: quantitative research, which focuses on numerical data, measurements, and statistical analysis; qualitative research, which explores words, images, and subjective experiences; and mixed methods research, which integrates both quantitative and qualitative techniques. The selection of an appropriate methodology is often informed by epistemological, ontological, and theoretical assumptions, as well as the researcher's worldview. For instance, if a researcher believes in an objective reality and holds a postpositivist worldview, he is inclined towards using quantitative research methodology that measures and models reality. Conversely, if research is guided by constructionist epistemology, the researchers will prefer using qualitative research methodology, which involves engaging with participants to interpret their perspectives. Meanwhile, an epistemological pluralist with a pragmatic worldview may opt for a mixed-methods approach, integrating both qualitative and quantitative techniques to address research questions more comprehensively. This section outlines the research methodology employed in this thesis, serving as the foundation for the overall research design, guided by the philosophical assumptions stated in Section 3.2.

### 3.5.2 Qualitative research – Strategies of inquiry

This thesis adopts a qualitative research methodology to explore the complex role of microgrids in the energy transition and the role of communities in implementing microgrid projects. The rationale behind adopting a qualitative research methodology is that it allows the author to understand the perceptions, expectations and attitudes of different stakeholders towards microgrid adoption. Bryman (2012) also stated that qualitative research is well-suited for capturing evolving events over time and understanding the interconnected actions of participants within social settings (Bryman, 2012). Therefore,

a qualitative approach is particularly valuable for examining the motivations and actions of community actors towards microgrid implementation. Understanding social perception, drivers, barriers, and community engagement requires interacting with diverse stakeholders to understand their experiences, attitudes, and thoughts towards the topic, which has been made possible with the qualitative analysis in the research (Creswell, 1994). Employing qualitative methodologies assists in capturing the depth and complexity of the subject matter, providing rich insights that quantitative methods might overlook. This is why quantitative research approaches, which are typically focused on numerical data and statistical analysis, are not adopted in the thesis, as this approach would've been insufficient for understanding the social aspects of microgrids, which involve complex human behaviours, perceptions and institutional interactions.

Various strategies guide qualitative research, enabling researchers to obtain meaningful and reliable results (Creswell, 1994). Table 4 outlines the key strategies of inquiry employed in qualitative research methodology.

*Table 4 Key strategies of inquiry in Qualitative Research Methodology*

<b>Strategies of inquiry</b>	<b>Elaboration</b>
<b>Narrative inquiry</b>	Involves the exploration of individuals' lives by inviting one or more participants to share their life stories. This information is typically restructured or retold by the researcher as a narrative chronology.
<b>Ethnography</b>	Focuses on the systematic study of people and cultures through immersive observation and participation, often over extended periods. Researchers strive to understand social phenomena from participants' perspectives and capture cultural practices, rituals, and norms in context.
<b>Case study</b>	Involves conducting an in-depth analysis of a specific case, which could be a program, event, activity, process, or individual(s). These cases are defined by clear boundaries in terms of time and place (or setting). Researchers gather comprehensive information through multiple data collection methods over an extended period.
<b>Grounded theory</b>	A sociological approach in which the researcher develops a general, abstract theory of a process, action, or interaction based on the perspectives of participants. This approach involves iterative stages of data collection and the systematic refinement and interconnection of information categories to construct a theory.

<b>Participatory action research</b>	Engages researchers and community members as co-collaborators in the research process. By integrating investigation with collective action, this strategy aims to promote practical, transformative outcomes beneficial to the community.
<b>Historical enquiries</b>	Investigates past events, processes, and social contexts to understand how they influence present situations. By analysing primary and secondary sources, researchers trace patterns and transformations over time.
<b>Phenomenology</b>	Explores the varied ways in which individuals perceive or experience a certain phenomenon. It maps the range of meanings and understandings people attach to the same concept or practice.
<b>Ethnomethodology</b>	Studies the everyday methods people use to construct and maintain social order. Researchers examine routine practices and interactions to uncover the often-implicit rules guiding behaviour.
<b>Discourse analysis</b>	Involves examining language-in-use, whether spoken or written. Linguistic approaches to discourse analysis focus on grammatical details and their role in communication.

This research adopts a combined grounded theory and case study approach to investigate the role of local communities in microgrid projects thoroughly.

#### 3.5.2.1 Grounded theory approach

Grounded theory facilitates the development of theoretical insights that emerge directly from the collected data, ensuring that findings are closely tied to the genuine experiences and perceptions of community members (BG & Strauss AL, 1967). This approach is particularly valuable for this research, as existing theories and research on the social aspects of microgrids do not fully capture the complexities of community engagement and acceptance. Additionally, grounded theory emphasises in-depth engagement with participants' perspectives and experiences, providing a rich, context-specific understanding of how communities perceive and adopt new energy technologies.

#### 3.5.2.2 Case Study Approach

This research also adopts a case study approach as a strategy of inquiry, as it enables an in-depth investigation of how microgrids and associated projects are perceived within a rural Australian community. A case study is particularly suited for exploring complex

socio-technical systems (such as microgrids), as it considers multiple variables, relies on diverse sources of evidence, and facilitates a comprehensive understanding of the topic (Yin, 2009). By thoroughly investigating specific communities or project sites, the case study approach provides a comprehensive view of local conditions, such as historical factors, cultural attitudes, policy environments, and stakeholder relationships, and how these factors impact microgrid adoption. This case study can also be replicated in other Australian communities or international microgrid projects. Thus, to enhance rigour and depth of analysis, this research integrates grounded theory with the case study method, creating a robust methodological framework.

### 3.6 Research Methods

Crotty (1998) defines research methods as the techniques and procedures employed to collect and analyse data in response to a research question or hypothesis (Crotty, 1998). These methods are essential components of the research process as they serve as data collection tools, facilitating the acquisition of information needed to address the research questions.

In qualitative research, research methods refer to the specific techniques used to collect rich, detailed data that capture the complexity of human experiences and social phenomena (Patton, 2014). These tools are important because they directly influence the depth and quality of the data collected, thereby affecting the validity and credibility of the research findings. Common qualitative data collection methods are listed in Table 5. The bold ones represent those that have been used in this research. By carefully selecting and employing appropriate data collection methods, researchers can ensure that they obtain meaningful and insightful data that contribute significantly to understanding the phenomena under study.

Table 5 Common qualitative data collection methods

Qualitative research methods	Explanation
<b>Observations</b>	Systematic recording of behaviours and events in their natural settings to gather firsthand data.
Sampling	The process of selecting a representative subset of a population for the purpose of analysis.
Measurement and scaling	Techniques used to assign numerical values to variables to quantify and compare attributes.
Statistical analysis	Application of statistical techniques to interpret and draw conclusions from collected data.
Data reduction	Simplifying and summarising large volumes of data to highlight essential information and patterns.
Theme identification	Detecting recurring patterns or topics within qualitative data to uncover underlying themes.
Comparative analysis	Evaluating two or more entities to identify similarities and differences for deeper insights.
Cognitive mapping	Creating visual diagrams to represent individuals' thoughts, beliefs, or perceptions about a topic.
<b>Document analysis</b>	Systematic examination of documents to extract meaningful information and understand context.
<b>Interviews</b>	Conducting one-on-one conversations to collect detailed personal perspectives and experiences.
<b>Surveys/questionnaires</b>	Using structured sets of questions to gather information from a larger audience efficiently.
<b>Workshops/focus group</b>	Facilitated group discussions to explore collective views and generate rich qualitative data.
Narrative storytelling	Collecting and analysing personal stories to understand how individuals make sense of experiences.
Visual ethnography	Visual media, such as photos or videos, can be used to study and represent cultural and social phenomena.
Dialogue	Engaging in open-ended conversations to explore and understand participants' viewpoints interactively.

This qualitative research employs semi-structured interviews, community surveys, and document analysis as primary data collection methods to comprehensively examine the role of local communities in microgrid studies, using supplementary data resources as well. Collectively, these methods form a triangulated approach that strengthens data

quality and enhances the validity of research outcomes. The following sections provide a detailed discussion of each method and the rationale for its selection.

### 3.6.1 Semi-Structured Interviews

Semi-structured interviews were used as a primary research method as a part of qualitative research. Semi-structured interviews allow for in-depth exploration of participants' experiences and perspectives while maintaining a structured approach to address key research questions (Maxwell, 2013). The flexible nature of semi-structured interviews makes them a valuable tool for exploratory studies (Ernst et al., 2018). These interviews are usually guided by the core questions, followed by the supplementary questions, allowing researchers to adapt questions based on participants' responses, enabling a deeper understanding of the topic. This adaptability also encouraged participants to share more detailed, context-rich information, often revealing insights that may not arise in more structured formats. This method has also proven to be effective in comprehending participant's attitudes, personal experiences, and the social context surrounding the research topic, providing a depth of understanding that quantitative methods often cannot achieve. Two types of semi-structured interviews were conducted in this research:

- a) Semi-structured interviews with the RRCRF project stakeholders (n=22)
- b) Semi-structured interviews with the community reference group and project stakeholders of the Heyfield community (n=13)

The details of semi-structured interviews are also mentioned in the methodology sections of Chapters 4, 5, and 6, as these chapters comprise the author's published work. However, a brief overview is also provided in this chapter for context.

#### 3.6.1.1 Semi-structured interviews with RRCRF-funded project stakeholders

In-depth semi-structured interviews were conducted with stakeholders drawn from twenty-two of the thirty-six projects funded by an Australian Government program, the

Regional and Remote Communities Reliability Fund (RRCRF). These stakeholders held key roles critical to developing microgrid feasibility within the different communities, including project managers, community liaison officers, senior engineers, energy specialists, and academic researchers. The diversity of participant roles enabled the study to understand the challenges, motivations, and perspectives associated with microgrid initiatives in remote and regional Australian communities.

#### 3.6.1.2 Recruitment and Participant Selection

The recruitment of participants was a multi-step process that began with identifying eligible stakeholders from the RRCRF-funded projects. Basic project information, such as the name of the project lead, the geographic location of the involved communities, the amount of funding awarded, and brief project descriptions, was sourced from the official funding database. Potential participants were approached directly if an existing professional relationship was in place or via a general inquiry to the lead organisation named on the grant funding page.

Initial contact was made through email invitations, which outlined the purpose of the research, the structure of the interview, and the voluntary nature of participation. Follow-up emails and a limited number of phone calls were made to encourage responses, aiming for an optimal balance between persistence and respect for non-responders' preferences. This comprehensive approach ensured a representative sample across different projects and regions, contributing to a deeper understanding of community engagement in microgrid projects.

#### 3.6.1.3 Interview Design and Implementation

The interview guide was designed based on identified research gaps in the existing literature on community energy projects, with a specific focus on the role of community engagement in the successful implementation of microgrids. Within this context, questions were designed to explore the motivations, barriers and perceptions, as well as

assessing the community engagement strategies and tools that were used. The interview guide is included in the appendix of Chapter 4.

Interviewees' participation was entirely voluntary, and no incentives were provided to ensure unbiased responses. The interviews were conducted online via videoconferencing platforms to facilitate participation from geographically dispersed stakeholders. Each session lasted between 30 and 50 minutes, allowing sufficient time for in-depth discussion while maintaining participant engagement. Of the thirty-six funded projects, nineteen accepted the invitation to participate, representing a significant portion of the RRCRF portfolio. These twenty-two interviews covered ninety out of the one-hundred-and-ten communities (approximately 81%) involved in the feasibility studies, providing a robust sample for analysing the engagement approaches.

### 3.6.2 Community Survey in Heyfield, Victoria

A community survey complemented the interviews by gathering data from a broader audience, allowing for the identification of patterns and trends that enhance the generalisation of the findings (Leknoi et al., 2022). To gain a broader understanding of community perceptions around microgrids, a community-wide survey (n=62) was conducted in Heyfield, Victoria, a rural town in Victoria, which was taken as a primary case study for the research. This survey assessed residents' awareness and perceptions of microgrids, their familiarity with the project outcomes, and their views on renewable energy microgrids. It included both closed- and open-ended questions, exploring key aspects such as the community's vision for an ideal power system, their level of familiarity with renewable energy technologies, and their willingness to adopt emerging innovations like microgrids. To ensure inclusivity and a representative sample, the survey was distributed through both online and in-person channels. The responses captured a diverse range of perspectives from individuals not directly involved in the project, providing valuable insights into the broader community's attitudes toward microgrids and

renewable energy adoption. Further details of the survey are provided in Chapter 6, and the survey questions are stated in the Appendix.

### 3.6.3 Supplementary Data Collection

Document analysis was conducted to review existing records, reports, and literature, providing contextual grounding for the research within the broader field while also corroborating findings from primary data sources. These included milestone reports, conference papers, news releases, articles, project websites, and other relevant publications. Additionally, publicly available materials published by the projects were examined to supplement the insights gained from interviews and surveys. These supplementary data sources provided context, background information, and verification for the interview data, strengthening the overall analysis. This approach ensured a comprehensive understanding of project developments, policy frameworks, and stakeholder perspectives, enriching the overall analysis.

The combination of semi-structured interviews and supplementary document analysis enabled a comprehensive exploration of community engagement practices, allowing for a nuanced understanding of how different stakeholders approached and navigated challenges in microgrid feasibility projects.

## 3.7 Data Analysis and Interpretation

The interview data underwent rigorous qualitative analysis, combining thematic analysis with a structured framework approach. Thematic analysis was selected as it allows for the systematic identification of patterns and themes across qualitative data. This process involved reviewing interview transcripts, coding, and developing a codebook that outlined the unit of analysis, initial categories, and emerging themes. Data was organised into nodes and sub-nodes using NVivo 12, which facilitated efficient coding and retrieval of

relevant segments, and themes were iteratively refined to ensure they accurately reflected the interview content.

The thematic analysis was conducted in several stages: initial data familiarisation, code generation, theme development, and review of the themes for dependability. The coding process was informed by the literature, particularly regarding the drivers and barriers of microgrid implementation, and allowed for the development of high-level themes and sub-themes that captured the core challenges, motivations, and insights shared by participants. In addition to thematic analysis, the data was analysed using different frameworks (mentioned in section 3.4) to better understand the social aspects related to microgrids.

### 3.7.1 Reliability and Validity of Data

Several methodological steps were taken to ensure reliability and validity in the qualitative data. Each interview was recorded with the participant's consent and transcribed verbatim. Transcripts were then carefully reviewed and cross-checked against the audio recordings to rectify any potential discrepancies. The data was analysed using a detailed codebook, with themes checked for consistency by multiple researchers to confirm dependability and reduce subjective bias. The use of NVivo 12 supported a structured and systematic analysis, which enhanced the traceability of the findings and allowed for transparent documentation of the analysis process.

### 3.7.2 Ethical Considerations

Ethical considerations were central to the research design, particularly given the study's reliance on personal perspectives shared by interviewees. The ethics application (approval number: ETH22-206 7296) was prepared and submitted by the author and subsequently approved by the university's Human Research Ethics Committee. The project was classified as low risk, and the application detailed the research methodology, participant recruitment processes, funding sources, disclosure of interests, and protocols for data collection, use, and participant involvement. Approval was granted to conduct both qualitative and quantitative components of the study.

Prior to participation, interviewees were provided with a Participant Information Sheet outlining the purpose of the research, reasons for their selection, potential risks, and how their data would be used. Contact information was included to address any questions or concerns. Data confidentiality was ensured, with personal details and names either de-identified or not disclosed publicly. Consent was obtained before each interview, confirming that participants understood the purpose of their contributions and the intended use of their responses.

Figure 17 illustrates the overarching research methods and analytical approaches employed in this study.

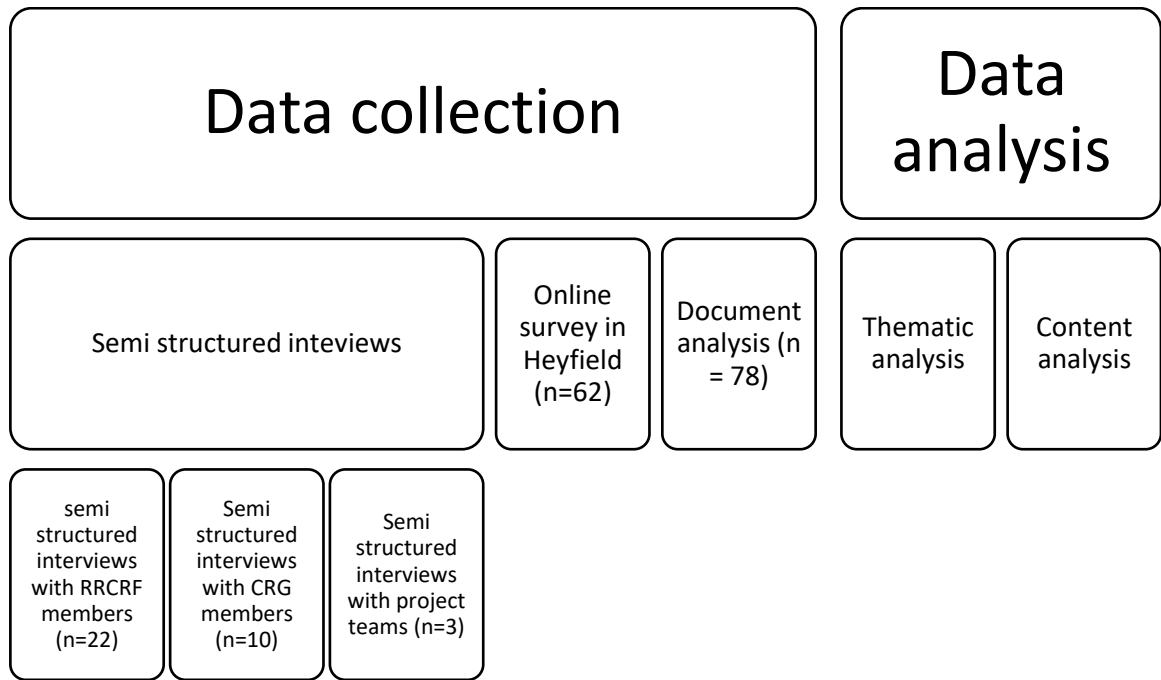


Figure 17 Overarching data collection and data analysis methods.

### 3.8 Conclusion

This chapter outlined the research strategy and methodological approaches employed to address the research aims and research questions presented in Section 1.3. This chapter has also established the researcher’s philosophical considerations and the theoretical foundations for analysing the role of local communities over a range of microgrid projects. The thesis adopts a qualitative research methodology integrated with grounded theory and a case study approach, which are well-suited to answering the research questions. By adopting the research methods and data sources, this research contributes new insights into the social dimensions shaping microgrid adoption in Australia and its critical role in the country's energy transition. Figure 18 demonstrates the overarching research design of this thesis. The next three chapters (Chapters 4, 5, and 6) present published work that builds on the methodology, philosophical considerations, and theoretical framework outlined in this chapter to address the research questions identified in Section 1.6.

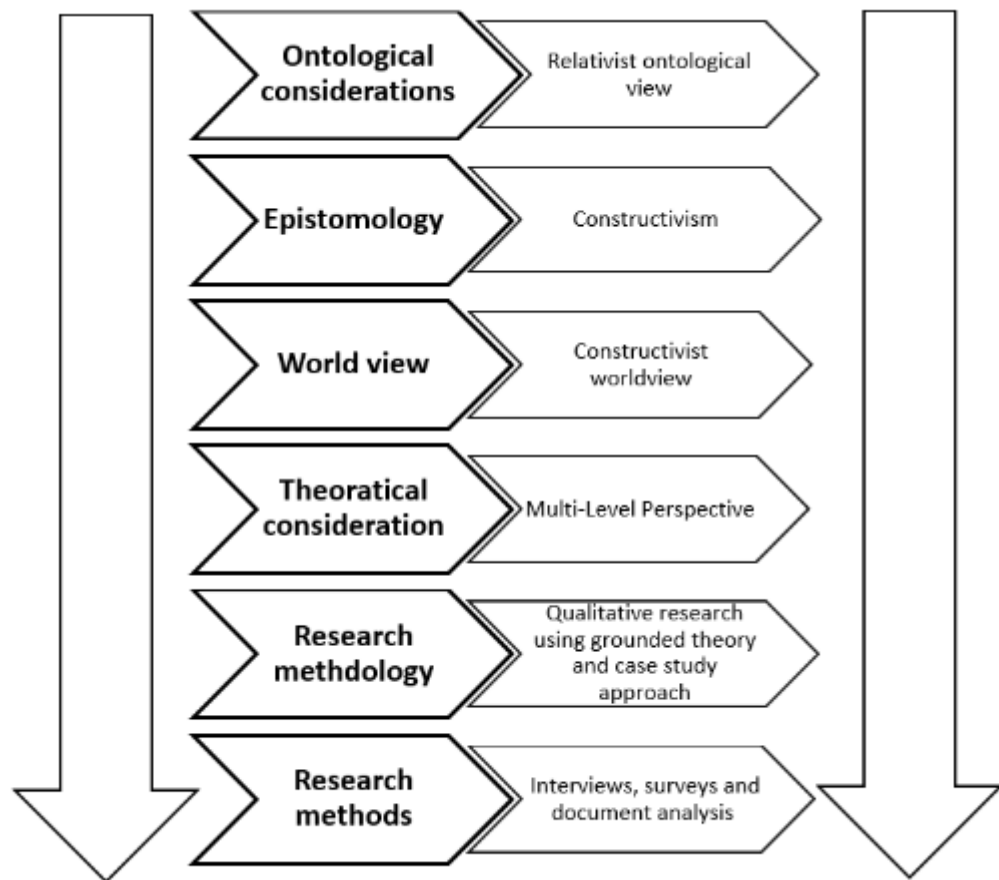


Figure 18 Overarching research design

### 3.9 References

- Arie Rip, & René Kemp. (1998). *Technological change* (S. Rayner & E. L. Malone, Eds.).
- B.A. Israel, A.J. Schulz, E.A. Parker, & A.B. Becker. (1998). Review of community-based research: Assessing partnership approaches to improve public health. *Annual Review of Public Health, 19*(1), 173–202. <https://doi.org/10.1146/annurev.publhealth.19.1.173>
- B.A. Israel, E. Eng, A.J. Schulz, & E.A. Parker. (2013). *Methods in community-based participatory research for health* (J. Bass, Ed.; 2nd ed.).
- Berkeley, N., Bailey, D., Jones, A., & Jarvis, D. (2017). Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take

- up. *Transportation Research Part A: Policy and Practice*, 106, 320–332.  
<https://doi.org/10.1016/j.tra.2017.10.004>
- BG, G., & Strauss AL. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*.
- Boudet, H. (2019). Public perceptions of and responses to new energy technologies. *Nat Energy*, 4, 446–455. <https://doi.org/10.1038/s41560-019-0399-x>
- Braithwaite, R., Cockwill, S., O'Neill, M., & Rebane, D. (2007). Insider participatory action research in disadvantaged post-industrial areas: The experiences of community members as they become Community Based Action Researchers. *Action Research*, 5(1), 61–74. <https://doi.org/10.1177/1476750307072876>
- Bryman, A. (2012). *Social Research Methods* (2nd ed.). Oxford University Press.
- Cannon, C., Bonnell, J., Padilla, M., & Sulca, D. (2023). Along the energy justice continuum: An examination of energy disposal through the lens of feminist community based participatory action research. *Energy Research and Social Science*, 96(December 2022), 102948. <https://doi.org/10.1016/j.erss.2023.102948>
- Creswell, J. W. (1994). Research design: Qualitative, quantitative, and mixed methods approaches. *The Oxford Handbook of Applied Linguistics*, (2 Ed.).
- Creswell, J. W. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
- Creswell, J. W. (2023). *Research design: qualitative, quantitative, and mixed methods approaches* (6th ed.). Sage Publications.
- Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process*. Sage Publications.

- Davis, S. M. (2007). Book Review: Methods in Community-Based Participatory Research for Health. In *Health Education & Behavior* (Vol. 34, Issue 1). <https://doi.org/10.1177/1090198106288490>
- Dwyer, F. R., & Tanner, J. F. (2002). *Business marketing: Connecting strategy, relationships, and learning*. McGraw-Hill.
- Elzen, B., Geels, F. W., Leeuwis, C., & van Mierlo, B. (2011). Normative contestation in transitions 'in the making': Animal welfare concerns and system innovation in pig husbandry. *Research Policy*, 40(2), 263–275. <https://doi.org/https://doi.org/10.1016/j.respol.2010.09.018>
- Ernst, A., Biß, K. H., Shamon, H., Schumann, D., & Heinrichs, H. U. (2018). Benefits and challenges of participatory methods in qualitative energy scenario development. *Technological Forecasting and Social Change*, 127(September 2017), 245–257. <https://doi.org/10.1016/j.techfore.2017.09.026>
- Feyerabend, P. K. (1981). *Problems of empiricism: philosophical papers*. Cambridge University Press, Cambridge,.
- Gavin J. Williams. (2013). 基因的改变NIH Public Access. *National Institute of Health*, 23(4), 1–7. <https://doi.org/10.1353/cpr.2012.0048>.Community
- Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. In *Research Policy* (Vol. 31).
- Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, 1(1), 24–40. <https://doi.org/https://doi.org/10.1016/j.eist.2011.02.002>
- Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, 36(3), 399–417. <https://doi.org/10.1016/j.respol.2007.01.003>

- Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). The Socio-Technical Dynamics of Low-Carbon Transitions. *Joule*, 1(3), 463–479. <https://doi.org/https://doi.org/10.1016/j.joule.2017.09.018>
- Genus, A., & Coles, A. M. (2008). Rethinking the multi-level perspective of technological transitions. *Research Policy*, 37(9), 1436–1445. <https://doi.org/10.1016/j.respol.2008.05.006>
- Guba, E. G. (1990). *The paradigm dialog*. Sage Publications.
- Israel, B. A. et al. (2019). Community-based participatory research. In *Urban Health* (pp. 272–282).
- Jerome Bruner. (1987). *Actual Minds, Possible Worlds*. Harvard University Press.
- Johnson, B., & R. Gray. (2010). A history of philosophical and theoretical issues for mixed methods research. In A. Tashakori & C. Teddlie (Eds.), *Sage handbook of mixed methods in social & behavioural research* (pp. 69–94).
- Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., ... Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, 31, 1–32. <https://doi.org/https://doi.org/10.1016/j.eist.2019.01.004>
- Leknoi, U., Yiengthaisong, A., & Likitlersuang, S. (2022). Community engagement initiative amid climate change crisis: Empirical evidence from a survey across Bangkok Metropolis of Thailand. *Cities*, 131. <https://doi.org/10.1016/j.cities.2022.103995>
- Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, 42(3), 237–246. <https://doi.org/10.1016/j.futures.2009.11.009>

- Maxwell, J. A. (2013). *Qualitative research design: An interactive approach: An interactive approach*. sage.
- Moon, K., & Blackman, D. (2014). A Guide to Understanding Social Science Research for Natural Scientists. In *Conservation Biology* (Vol. 28, Issue 5, pp. 1167–1177). <https://doi.org/10.1111/cobi.12326>
- Muttaqee, M., Furqan, M., & Boudet, H. (2023). Community response to microgrid development: Case studies from the U.S. *Energy Policy*, 181(December 2022), 113690. <https://doi.org/10.1016/j.enpol.2023.113690>
- Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. [https://inctpped.ie.ufrj.br/spiderweb/pdf\\_2/Dosi\\_1\\_An\\_evolutionary-theory-of\\_economic\\_change..pdf](https://inctpped.ie.ufrj.br/spiderweb/pdf_2/Dosi_1_An_evolutionary-theory-of_economic_change..pdf)
- Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.
- Perera, R. (2017). *The PESTLE analysis*. Nerdynaut.
- Pratt, D. D. (1998). *Five Perspectives on Teaching in Adult and Higher Education*.
- Ravitch, S. M., & Riggan, M. (2016). *Reason & rigor: How conceptual frameworks guide research*. Sage Publications.
- Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of Industrial Ecology*, 13(2), 184–196. <https://doi.org/10.1111/j.1530-9290.2009.00116.x>
- Simon Frankel Pratt, Thomas Jamieson, & R. Huddleston. (2022). Chapter 2: Epistemology: logic, causality, and explanation. In *Handbook of Research Methods in International Relations* (pp. 25–40).

- Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, 34(10), 1491–1510.  
<https://doi.org/https://doi.org/10.1016/j.respol.2005.07.005>
- Sovacool BK. (2010). *The Routledge handbook of energy security*.
- Tashakkori, A., & C. Teddlie. (2010). *Sage handbook of mixed methods in social & behavioural research*. Thousand Oaks, California.
- Thomas A Schwandt. (2000). *Three epistemological stances for qualitative inquiry: Interpretivism, hermeneutics, and social constructionism*.
- Unruh GC. (2000). Understanding carbon lock-in. *Energy Policy*, 28, 817–830.
- Yin, R. K. (2009). *Case study research: Design and methods (Vol. 5)*. Sage Publications.
- Yüksel, I. (2012). Developing a Multi-Criteria Decision Making Model for PESTEL Analysis. *International Journal of Business and Management*, 7(24), 52–66.  
<https://doi.org/10.5539/ijbm.v7n24p52>

# Chapter 4

## Emergent Opportunities and Barriers on the Feasibility of Microgrids: Qualitative Findings from an Australian Funding Program

**Based on a Publication in Energy Research and Social  
Science**

**Volume 109, March 2024, 103423**

**<https://doi.org/10.1016/j.erss.2024.103423>**

# Chapter 4. Emergent Opportunities and Barriers on the Feasibility of Microgrids: Qualitative Findings from an Australian Funding Program

## 4.1 Introduction to the Chapter

This chapter presents findings from a published article titled "Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program" which has been published in *Energy Research and Social Science*. The chapter directly addresses the first research question of this thesis: What are the major barriers and opportunities in microgrid-related studies in Australia, and how do these compare to those assumed in the international literature? Through an analysis of the microgrid feasibility studies in Australia, the chapter provides insights about key drivers and barriers in microgrid feasibility studies and how these relate to the existing literature. The Chapter employs the PESTEL framework (as a part of the integrative approach stated in Chapter 3, section 3.4) to explore both technical and non-technical challenges. The chapter aims to provide insights to inform future microgrid funding policies and programs for the benefit of those living in rural and remote communities.

## Abstract:

Climate change is having widespread impacts worldwide, with rural and remote regions particularly at risk from the worst effects. Communities in these areas are responding by seeking to ensure an electricity supply that is more resilient, reliable, affordable, and cleaner. Microgrids are increasingly being deployed worldwide to provide these outcomes, but their application remains limited in most markets today. In 2019, the Australian government announced a grant program that would see almost \$AUD45 million in funding for microgrid feasibility studies for over 110 communities across Australia. Interviews were conducted with participants from a large proportion of these government-funded projects to explore the barriers encountered and how these compare to those cited in the international academic literature. It was found that the main barriers in Australia were related to the policy and regulatory framework, business models and a lack of transparency over revenues and costs, maintaining sustained levels of community engagement, and bridging the gap between feasibility and implementation. The findings can support increased microgrid deployment in Australia and overseas while helping inform future associated policies and programs to benefit those living and working in rural communities.

# 1. Introduction

Since the start of the Industrial Revolution, human activity has led to the highest carbon emission levels in two million years, increasing the likelihood and severity of extreme weather events (IPCC Report, 2021). Australia has been particularly prone to these, with its Bureau of Meteorology reporting 122 extreme weather events in 2022 alone (Meteorology, 2022). Rural and remote communities have been disproportionately impacted by these (Freeman Julie & Hancock Linda, 2017). While government agencies have been active in providing support and services to those affected, communities have also responded with increased interest in local renewable energy projects to improve the resiliency and reliability of energy supply (Hicks & Ison, 2011; Niklas et al., 2022).

Considerable government funding has been made available to support these projects in Australia. The Australian Renewable Energy Agency (ARENA) has invested over \$AUD1.7 billion in more than 600 projects (ARENA, 2023a). The Clean Energy Finance Corporation (CEFC) has provided approximately \$AUD10 billion in finance to more than 1000 renewable energy projects (CEFC, 2023). Collaborations between industry and research have also successfully secured government funding, such as the RACE for 2030 Cooperative Research Centre, which received \$AUD68.5 million from the Federal Government and was then matched by the industry for research into reliable, affordable, and clean energy (RACE for 2030, 2023). While the funded projects have been more broadly aimed at increasing the supply of renewable energy, only some have focussed on the challenges of community energy resiliency amidst a changing climate. One such program was the Federal Government's Regional and Remote Communities Reliability Fund - Microgrids (RRCRF). With around \$AUD45 million in funding provided to conduct community microgrid feasibility studies for one hundred and ten communities between 2020 and 2024, the RRCRF program aimed to help businesses and communities in rural

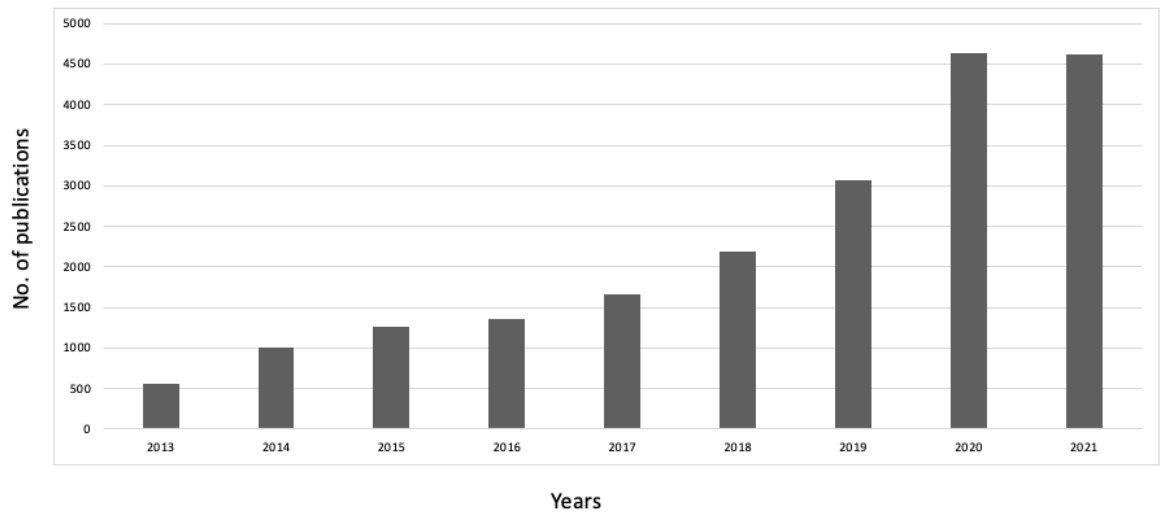
and remote areas become more energy resilient while addressing the barriers to microgrid deployment (Department of Climate Change, Energy, the Environment, 2022).

This paper presents the empirical findings from semi-structured interviews with key stakeholders involved in these government-funded microgrid feasibility studies. Perceptions of the drivers and barriers were explored with interviewees to understand how those they experienced relate to those described in the international academic literature. The paper also provides policy recommendations that can assist in designing future energy funding programs, help inform future microgrid projects, and contribute towards a new national regulatory framework for microgrids in Australia.

## 2. Literature Review

### 2.1 Definitions of microgrids: a confusing territory

The term 'microgrid' has become popularised over the last decade in both academic and non-academic literature. Approximately 4700 academic journal papers published on microgrid-related topics have included a definition. These definitions have been found to typically depend on the perspective of the research or sometimes on the convenience of calling a particular project a microgrid (Basak et al., 2012; Feng et al., 2018; Jiayi et al., 2008; Ustun et al., 2011). Different applications and configurations have also made defining what a microgrid is more challenging (Guibentif & Vuille, 2022). Figure 19 highlights the number of journal articles published on microgrids.



*Figure 19 Number of journal articles published on microgrids*

The Scopus Database has also shown that the term “microgrid” featured in 570 publications in 2013, whereas this number rose to 4799 in 2021, almost eight times more.

One of the most highly cited definitions (Olivares et al., 2014) was developed by the US Department of Energy (Pesin, 2017) with the help of a stakeholder group that defined microgrids as “a group of interconnected loads and distributed energy resources, which are operated in a particular electrical boundary as a single controllable entity. A microgrid can connect or disconnect from the grid and operate independently in the islanded mode” (Olivares et al., 2014; Perez-DeLaMora et al., 2021; Pesin, 2017; Ton & Smith, 2012).

The definition developed by the International Council on Large Electrical Systems (CIGRE) and US CERTS has also been used extensively in the literature (CIGRE Working Group C.22, 2015; Lasseter, R. et al., 2002; Madureira, 2010; Martin-Martínez et al., 2016; Romankiewicz et al., 2014). Some researchers have also defined microgrids as an interconnection of Distributed Energy Resources (DERs) to supply reliable power to the local community. In contrast, others have viewed an islanding feature (ability to operate independently of the grid) as necessary to be considered a microgrid (Ajaz & Bernell, 2021; Guibentif & Vuille, 2022; Hatziargyriou, 2013). Funding agencies have understandably found it necessary to include definitions in their guidelines. For the RRCRF program, a microgrid was defined as “An electricity supply arrangement that can

(but may not always) function autonomously and generates and supplies electricity to multiple customers” (Regional and Remote Communities Reliability Fund Microgrid, 2021).

In this research, we will use the highly cited definition by the US Department of Energy because of its extensive nature, including microgrid boundary, islanding feature and operation independent of the grid.

## 2.2 Microgrid configurations and applications

Microgrids can be grid-connected or non-grid connected. Grid-connected microgrids maintain a connection with the main electricity grid and can both export and import energy from it. Non-grid connections cannot do this and are more likely to be found in more remote areas or small islands (Cagnano et al., 2020; Kabalci, 2018; Katiraei et al., 2004; Meje et al., 2020). For those that are grid-connected, by definition, they should be capable of operating in islanding mode, where they temporarily disconnect from the main grid but maintain a continuous supply of power to the loads at this time.

The literature also highlights three major categories that classify microgrids based on the type of power they can supply to distribution networks. These are AC (alternating current) microgrids (A. Mohammed et al., 2019; Planas et al., 2015; Y. Wu et al., 2019), DC (direct current) microgrids (Kabalci, 2018; Martin-Martínez et al., 2016; Meje et al., 2020; R. A. F. Ferreira et al., 2013; Ullah et al., 2020), and hybrid microgrids (which integrate both AC and DC power sources, storage, and loads) (Meje et al., 2020; Rezkallah et al., 2019; Temene Hermann et al., 2022; Unamuno & Barrena, 2015). Microgrids can be deployed for a variety of different applications, including remote islands or communities, agricultural operations, university campuses, military bases, and commercial and industrial (C&I) precincts, to name a few (B. Richter et al., 2019; C. Echave, D. Ceh, 2019; Hadjidemetriou et al., 2018; Perez-DeLaMora et al., 2021; Rezkallah et al., 2019).

## 2.3 Microgrid drivers

Microgrid drivers have been well explored in the academic literature (Farrelly & Tawfik, 2020; Hirsch et al., 2018; Pullins, 2019; Wei & Chen, 2019). Hirsch et al. (Hirsch et al., 2018) categorise the drivers under three broad categories: energy security, economic benefits, and clean energy integration. The same classification was highly cited in the literature and was found to be a simple yet versatile way of understanding microgrid drivers (and expanding upon them) as part of this research.

Drivers within the energy security category may include a community's desire for improved energy resilience during extreme weather events (Farrelly & Tawfik, 2020; Hirsch et al., 2018). Improved energy reliability can also be classed under the energy security category, particularly for communities that have faced issues such as poor power quality and regular power outages (Newman, 2015). The economic benefits category of drivers would include communities that seek to reduce their reliance on diesel generators and the associated high fuel and maintenance costs. Many remote communities worldwide rely on diesel generators for their energy supply (Bebic, 2011; Denholm et al., 2015). Reducing reliance on diesel generators and transitioning towards cost-effective and affordable electricity are major drivers for communities to shift towards microgrids (Grisales-Noreña et al., 2023). Electricity distribution companies are also looking to reduce the cost of expensive infrastructure investment and maintenance to supply communities far from the main grid while improving electricity affordability for all consumers (Grisales-Noreña et al., 2023). Clean energy integration is a category of driver that includes integrating clean energy resources, like solar PV and wind, and implementing new sustainable energy alternatives to reduce carbon emissions from power generation (Ajaz & Bernell, 2021; Bebic, 2011; Denholm et al., 2015; IEA, IRENA, UNSD, WB, 2019).

## 2.4 Barriers in the existing literature:

The barriers that hinder the more rapid deployment of microgrids have been explored extensively in the academic literature (Brummer, 2018; Soshinskaya et al., 2014; Wouters, 2015). The existing literature stated the absence of a suitable regulatory framework is the major barrier to microgrid implementation (Farrelly & Tawfik, 2020; Marnay & Giri Venkataramanan, 2006; Wang et al., 2018; Wouters, 2015). Determining a viable business model and ownership structure of the assets deployed in the community constitutes a critical aspect of the feasibility studies (Gui et al., 2017; Hanna et al., 2017). Lack of capital and access to funding is another significant barrier that features heavily in the literature (Brummer, 2018; Guerrero M. Josep et al., 2013; Lukas Weber, 1997; Soshinskaya et al., 2014). The existing literature also highlights that the lack of trust between the local community representatives and the project team can be a significant barrier to the project (Benjamin J.A.Walker et al., 2014; Coy et al., 2021; Soshinskaya et al., 2014; Walker et al., 2010). From a technological perspective, the literature highlights barriers associated with operating the islanding mode of microgrids (Tao et al., 2011) such as issues related to voltage imbalance, frequency regulation and synchronising issues between grids (Agarwal & Mittal, 2011; Katiraei et al., 2004; Kojima, n.d.; Marnay et al., 2008; Soshinskaya et al., 2014).

## 2.5 Australian energy system and energy transition trends:

The Australian energy system still primarily relies on centralised, carbon-intensive non-renewable fossil fuels, with coal and gas accounting for 70% of the country's total generation in 2021 (Regulator, 2023). However, renewable energy generation has been increasing considerably over the last decade. Its share of the entire energy mix has risen by 18% over three years, from 11% in 2019 to 29% in 2021 (Energy.gov.au, 2022). The Australian government has released its Long-Term Emissions Reduction Plan to achieve net zero by 2050 and is planning to invest \$20 billion in innovative technologies (Clean

Energy Council, 2019). This growth has been driven by supportive government subsidies and policies, declining technology costs, and increasing consumer awareness of the benefits. Solar and wind are now the cheapest source of energy generation, with the levelized cost of large-scale solar expected to further reduce from between \$44 and \$65/MWh currently to between \$27 and \$56/MWh by 2030, further accelerating the uptake of solar and wind in Australia (Council, 2022).

Australia is the 6th largest country in the world regarding landmass, sitting between Brazil (214 million people) and India (1.4 billion people). However, it has only 25 million inhabitants. The population outside the main metropolitan areas is highly dispersed, with 8.5 million people living in rural towns, villages, and remote regions (ABS, 2023). Remote communities in Australia are typically “off-grid” without access to the electricity network, with future connections unlikely due to the cost of supplying the power in those regions (AEMC, 2023). This can make delivering a resilient and reliable electricity supply challenging and costly across these long distances (AEMC, 2022; ARENA, 2022; Ekistica, 2018; Lu et al., 2015b). Another challenge for more remote communities is expensive electricity due to the high fuel costs that stem from the need to use diesel generators (ARENA, 2022).

Understandably, interest in microgrids for rural and remote areas has increased in Australia because of their potential to address some of these issues. In terms of energy supply, microgrids can provide improved resiliency (Soshinskaya et al., 2014), reliability (Ilindala et al., 2007; Shahidehpour & Clair, 2012; Wu et al., 2016), and energy security (Lu et al., 2016; Onu et al., 2023; Sovacool & Mukherjee, 2011). Microgrids have also been found to improve power quality, reduce frequency fluctuations and voltage imbalance, and improve power losses (Golpîra & Bevrani, 2019; Suman et al., 2022).

## 2.6 Australian funding program for microgrid feasibility studies:

To accelerate the deployment of microgrids in rural and remote communities, the Australian Government provided almost \$AUD45 million in funding to thirty-six community microgrid feasibility studies that would run between 2020 and 2024. This would see feasibility studies conducted for one hundred and ten communities. The RRCRF program was created to help businesses and communities in rural and remote areas become more energy resilient while addressing the various barriers to microgrid deployment (Regional and Remote Communities Reliability Fund Microgrid, 2021).

In August 2023, ARENA announced the launch of a subsequent program to fund the development and deployment of microgrids in rural areas. The Regional Microgrids Program makes up to \$AUD125 million for eligible projects (ARENA, 2023b).

The definitions for the RRCRF funding (2020-2024) and subsequent Regional Microgrid Program (2023-2025) are provided below and in both cases, represent a broader definition of the term “microgrid”.

Table 6 Comparison between RRCRF and Regional Microgrid Funding Programs

Funding Program	Regional and Remote Communities Reliability Funding (RRCRF)	Regional Microgrid Program
Microgrid Definition	<i>“An electricity supply arrangement that can (but may not always) function autonomously and generates and supplies electricity to multiple customers.”</i>	<i>“For the purposes of the Program, the term microgrid is used to include the following technical configurations: a. Embedded Microgrid, which is an electricity supply arrangement that coordinates and optimises the use of connected, locationally proximate distributed energy resources (DER) to provide secure and reliable electricity. b. Standalone Power Systems (SAPS): An electricity supply arrangement that can operate when not physically connected to a major grid. c. Remote Isolated Microgrid: An electricity supply arrangement that already operates as an isolated SAPS and will continue to do so in rural and remote locations</i>
Funding body	Federal Government	ARENA
Years	2020 – 2024: Funding runs for five years (awarded in two stages).	2023-2025 (awarded for two streams: Regional Australia Microgrid Pilots (Stream A) and First Nations Community Microgrids (Stream B))
Available Funding	\$45 million	\$125 million (\$AUD50 million for Stream A and \$AUD75 million for Stream B).
Project Type	Feasibility	Implementation
Description	“The fund supports feasibility studies looking at microgrid technologies to replace, upgrade, or supplement existing electricity supply arrangements in off-grid and fringe-of-grid communities in regional and remote areas.”	“To support improved resilience and reliability of electricity supply in regional Australia through pilot microgrid demonstrations that use or enable the use of renewable energy and resolve the remaining barriers to find investment and full deployment and to deploy microgrids across First Nations communities to increase access to cheaper, cleaner and more reliable energy.”
Grant amount	Minimum AUD100,000 and maximum AUD10 million	Minimum \$AUD1 million, maximum \$AUD10 million (Stream A), and \$AUD25 million (Stream B).
Number of grants awarded	36	None at the time of publishing
Number of communities featured	110	None at the time of publishing

## 2.7 Research gap and research questions

Interest in microgrids is being driven globally by a variety of issues relating to energy security, economics, and increased penetration of renewable energy technologies. These issues are also highly pertinent for Australia, given its geography, climate, population, electricity grid, and vulnerability to increasingly extreme weather. However, many barriers are cited in the international literature, such as the current regulatory framework, lack of a prevalent viable business model, lack of funding, and technical challenges of islanding and trust. A major funding program funded microgrid feasibility studies for over 100 rural and remote communities. This provided a unique opportunity to understand and confirm the prevalent drivers and barriers for microgrids in Australia based on the experiences of those directly involved. The research question guiding our research is stated as: “What are the drivers and barriers associated with the microgrid feasibilities in the regional and remote Australian communities, and how do these compare with the existing literature?”

## 2.8 Theoretical framework: PESTEL Framework for the microgrid barriers

The authors have adopted the PESTEL framework as an analytical tool to categorise the barriers for microgrids in Australia. The PESTEL framework was initially developed to provide a situational analysis of a business and identify and categorise different threats and opportunities (Perera, 2017). The framework also characterises the macro-environment for various contexts as each letter represents an aspect of that environment, i.e., Political, Economic, Social, Technological, Environmental and Legal (Dwyer & Tanner, 2002; Yüksel, 2012). The categorisation of the factors in these dimensions help gain a comprehensive perspective on the complex macro-level influences.

This research adopted the PESTEL framework to categorise and code the barriers uncovered in the interviews. This enabled the characterisation of the macro-environment for microgrids and their funded feasibility projects. The framework serves as a valuable tool in categorising barriers in microgrid studies, offering a structured, comprehensive, and standardised approach that contributes to a deeper understanding of the challenges and opportunities in microgrid feasibility studies.

### 3. Method

While the RRCRF funding program successfully accelerated interest and microgrid feasibility activity across Australia, there was no obligation or mechanism to share and compare findings across the thirty-six projects. To better understand the opportunities and barriers emerging from these and how they relate to those cited in the international academic literature, in-depth semi-structured interviews were conducted with key stakeholders directly involved in the projects. This qualitative research methodology provided detailed information regarding the personal perspectives and experiences of the participants involved (Patton, 2014).

#### 3.1 Participant Selection and Identification:

The first step for conducting the interviews was the identification and selection of interviewees from each of the RRCRF-funded projects. Details on each project were available on the funding website pages, including the organisations involved. Contact details for individuals linked to the different projects were sourced from the authors' existing connections. General contact details were sourced from company web pages where no relationship existed. Interview invitations were sent to the participants via email and were regularly followed up until the interviews were scheduled. In total, nineteen interviews were conducted, representing 70% of the RRCRF-funded projects, as some

interviewees were involved in multiple projects across different communities. Table 7 summarises the interview details below:

*Table 7 RRCRF-funded projects and interviewee key details*

<b>Total number of funded projects</b>	36
<b>Total number of communities involved</b>	110
<b>Total number of interviews conducted</b>	19
<b>Total number of projects covered</b>	25 (70%)
<b>Total number of communities covered in the interviews</b>	70 (64%)
<b>Role of interviewees</b>	<ul style="list-style-type: none"> <li>- Project Managers</li> <li>- Community Engagement</li> <li>- Managing Directors</li> <li>- Clean Energy Community Coordinators</li> <li>- Senior Engineers</li> <li>- Associate Professors</li> <li>- Energy Experts</li> </ul>
<b>Types of organisations (and % of total projects with them listed as a core partner)</b>	<ul style="list-style-type: none"> <li>- Energy utility (32%)</li> <li>- Technology companies (16%)</li> <li>- Energy consulting companies (24%)</li> <li>- Community groups (11%)</li> <li>- Universities (8%)</li> <li>- Research groups (3%)</li> <li>- Investment companies (3%)</li> <li>- Agricultural industry (3%)</li> </ul>

The participants selected for the interview covered a wide range of roles, from technology company managers, senior engineers, and project managers to members of community groups, chief investigators of the project and university professors. This diverse portfolio allowed a broader exploration of the major drivers and barriers experienced within these feasibility studies. Figure 20 shows the types of organisations involved as major stakeholders in the RRCRF-funded projects.



Figure 20 The type of organisations involved in the RRCRF-funded feasibility studies as major partners.

### 3.2 Semi-structured interviews

The interview guide (see Appendix A) was developed for data collection based on the literature review and the research gaps. The interviewees' participation was purely on a volunteering basis, with no incentives for participating in the interviews. The interviews were conducted online, ranging from 30 – 50 minutes, with a discussion on different microgrid feasibility projects, the project inception, associated barriers and opportunities, and the drivers related to the projects. The core interview questions were based on the drivers, barriers, community engagement strategies, and proposed business models. While the interviewees were all in pivotal positions in their respective projects, their official roles and fields of expertise were diverse. 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 with such a varied cohort of interviewees.

However, a shortcoming of this approach is the risk of interviewer and social desirability bias (Sovacool et al., 2018). To address this, the qualitative interview data was carefully

recorded, transcribed, cross-referenced, and analysed by multiple researchers to minimise the risk of bias.

Another potential shortcoming was the number of interviews (n=19), where an insufficient number could result in conflicting or indeterminate perspectives. While additional interviews would have been welcome and added to the richness of the data collected, the final number of interviews that were undertaken represented the majority of projects (70%) and communities (64%) funded by the RRCRF program.

A thematic analysis approach was used to analyse the qualitative data gathered from the interviews. The thematic analysis involved the review of data, determining the unit of coding, establishing a codebook, identifying themes, and checking for dependability (Guest et al., 2020). The interviews were recorded with the participants' permission and transcribed carefully using software for the 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 data were categorised into nodes and sub-nodes. The microgrid drivers are coded against three distinct categories, i.e., energy security, energy reliability and clean energy integrations, along with emerging themes from the interviews. The data is also coded and analysed through the PESTEL framework to categorise the barriers related to microgrids.

## 4. Results

The results gathered from the research have been highlighted in the following sections.

### 4.1 Different Perceptions of Microgrids

One of the first questions the interviewees were asked was how they defined a microgrid. This was tested to understand how those involved in the microgrid feasibilities interpreted the definition of a microgrid. One of the interviewees commented, *“If we get ten energy experts in the room and ask the question, we will get ten different definitions.”*

The word cloud in Figure 21 shows how the interviewees involved in the government-funded microgrid feasibility studies defined a microgrid in their own words. The higher frequency words used by the interviewees clearly associated their perception of microgrids with key features of their functionality, such as being “grid connected”, and with the ability to “island” or “isolate” from the main grid. The mid frequency words used were those more closely linked with aspects of a microgrid’s operation (“intelligent”, “generation”, “interconnection”) and associated drivers (“resilience”). Lower frequency words (such as “battery storage”, “sharing”, “critical”, and “feeders”) relate to the interviewee’s perceptions of microgrids as a tool for power sharing and storage, as well as implying their crucial role in future electricity distribution network infrastructure.

The Australian funding programs aimed at microgrid feasibility (the Australian Government’s RRCRF Program) and subsequent microgrid implementation (ARENA’s Regional Microgrids Program) also developed definitions that broadly aligned with contemporary definitions. However, they did not include the pre-requisite that a microgrid be islandable, a key feature cited in the literature, which may have been designed to ensure a less restrictive definition and applicability to more communities.



Figure 21 Word cloud of words used to describe interviewees' definition of a microgrid

## 4.2 Microgrid Drivers from the Research

The specific drivers provided by the interviewees are given in the sections below:

### 4.2.1 Energy Security

The interviewees involved in Australian microgrid feasibility studies also revealed energy resilience to be the major driver for the project. One interviewee highlighted the devastating effects of bushfires in 2019, which saw the town lose power for days, destroying the telecommunication, transport, and sewage systems. This desire for better energy resiliency led the community stakeholders to apply for funding. The interviewee

involved in the project in Queensland stated: *“The main drivers for that particular microgrid were the bushfires at the end of 2019 and early 2020, where half of the community was basically burnt down. And a lot of the properties around the surrounding a surrounding area were destroyed.”*

This was similar for communities in Western Australia, impacted by floods in 2022, with major roads cut off along with the diesel supply for their generators. Another interviewee mentioned a rural community in Victoria, which was affected by heavy storms in June 2020, leaving residents and businesses without internet, power, and communication. This has led to the broad reflection from actors, including local community organisations, on the need to rethink the local energy system when sections of their community are made to go without power for 1-2 weeks.

#### 4.2.2 Energy Reliability

Many microgrid feasibility studies in Australia have aimed to improve energy reliability in remote communities. An interviewee involved in the microgrid feasibility study in a small remote community in Western Australia highlighted that the town is on a 100 km radial line. Any fault on that line can disrupt the power supply in the whole town. Similarly, some towns in the tropical and sparsely populated Northern Territory experience a high degree of power outages. Interviewees involved in feasibility studies in Victoria highlighted that communities located at the fringe of the grid frequently face power outages. An interviewee mentioned, *“The communities that were chosen for the feasibility study of a microgrid were communities that are at the end of the power grid. So there's some in the past that have seen some issues with some power outages. And so the proposition, I guess, is that microgrid can support these communities, more with energy reliability.”*

Another issue highlighted by the interviewees related to the reliable supply of electricity is the presence of single electricity distribution lines in the region (known as “Single Wire Earth Return” – or “SWER” – lines), which can be more prone to voltage fluctuations and

voltage instability. One of the interviewees investigating microgrid feasibility for farms in Queensland also highlighted the power reliability issue as the most significant driver for agricultural businesses to seek alternative power supply arrangements. The power outages and voltage fluctuations in the farms can degrade the machinery and severely disrupt the farming process. The farmers at the end of the line experienced outages that lasted 1-2 weeks before someone could restore power. The interviewees from the projects in the states of New South Wales and Tasmania have also stated that the reliability of electricity is the major driver for their respective projects due to peak demand in tourist destinations and overloaded transmission lines.

As stated earlier, most of the remote communities in Australia are at the fringe of the grid, where the electricity is supplied through a single line. When a fault occurs on the transmission line, the town can lose power for several hours. The communities do not have the local personnel and skilled workers to clear these faults. In remote regions, as stated by the interviewee, it can take 1-2 days for the network providers to send help to the faulted site before they can clear the fault. The remote communities in Queensland have experienced power outages for 2-3 days. This has driven the communities to be self-sustainable and skilled enough to deal with these situations independently.

#### 4.2.3 Economic Benefits

A number of the Australian feasibility studies involved communities that used diesel generators as their main source of power generation, and reducing reliance on these generators is one of the major drivers for their interest in microgrids. The communities are interested in understanding if microgrids that use renewable energy and storage are feasible to provide cheaper electricity while reducing or removing reliance on diesel generators as their primary power source. The interviews found that this was a major driver for many communities, regardless of which state and whether the communities featured residential, business, or agricultural energy consumers.

#### 4.2.4 Clean Energy Integration

An interviewee mentioned that state-based decarbonisation targets have also driven participation in these feasibility studies. Referring to the Northern Territory government's target (70% renewable energy generation in remote communities by 2030), agricultural and commodities businesses were encouraged to consider how microgrids could benefit them by participating in RRCRF-funded projects. The microgrid feasibility study in South Australia was also driven by reducing the reliance on diesel generators and promoting renewable energy in the region. The interviewee involved in the feasibility study in the mid-sized rural town of Victoria highlighted that the community survey revealed the reduction in carbon emissions as the major driver for the local community. One interviewee stated: *“If net zero is to be achieved, it is important to shift away from synchronous generators and start exploring energy storage options for the evening peak of households.”*

#### 4.2.5 Community response to the new technologies

Some interviewees discussed how interest in microgrids within their communities is driven by an eagerness to try new technologies and test new concepts. For one of the feasibility studies conducted for a town in Victoria, a major driver for the community to be interested in microgrids was that they had already installed solar PV and batteries in their homes, and a microgrid was a further step towards adopting new energy technologies. To address this desire for new energy concepts, the project team had to use a variety of tools to educate the community with workshops, white papers, seminars, and face-to-face engagements. The interviewees also spoke of the risk that new technologies can be attractive but could demotivate a community if it becomes attached to a particular concept and it is found not to be a suitable option.

## 4.3 Microgrid Barriers

As previously discussed, the global microgrid market is still in its infancy, and Australia's community microgrids are still mainly at the pre-feasibility stage, with only some early pilots. Interviewees were asked about the barriers they experienced in their microgrid feasibility projects. Most of the barriers identified in the literature coincide with those the interviews revealed being experienced in the Australian microgrid feasibility studies. However, other barriers specific to the Australian context were also uncovered. The following section summarises the emergent barriers highlighted by the interviewees mapped against the PESTEL framework and how they relate to those in the literature.

### 4.3.1 Political

Most interviewees stated a lack of a clear regulatory framework around microgrids as the main barrier in their respective projects. The regulatory framework in Australia varies by state, making it challenging to regulate uniformly at the Federal level. One interviewee specified how this barrier, in particular, is hindering microgrids from moving through the usual steps of project design, developing and receiving the revenue contract, and then connecting to enable the supply of power to the community. Another interviewee declared the lack of a consistent national framework as a major barrier, particularly one that provides a clear position and support in microgrids' design, operation, and ownership.

The COVID-19 pandemic also had disastrous effects globally on multiple levels, and the microgrid feasibility studies initiated between 2020 and 2022 were impacted significantly. Strict laws were implemented in Australia and to varying degrees between states. With interstate travel (and in some cases intrastate) not possible, interviewees faced issues in undertaking the levels of community engagement needed for effective microgrid feasibility. Site selection was impacted by this as physical inspection of sites was hindered. Installation of energy monitoring devices was impacted significantly as constraints were placed on when electricians could enter the premises.

One of the project's interviewees stated that COVID-19 restrictions significantly hindered community engagement activities, resulting in lost time and resources. Another interviewee mentioned how restrictions impacted the equipment delivery schedule and led to long wait times, affecting the project schedule. In the remote communities of Western Australia, restrictions also meant that electricians and technical staff were prevented from entering communities, causing delays in data collection.

### 4.3.2 Economic

The reservations of community members regarding ownership structure were considered a major barrier for many of the project stakeholders. For some projects, the consideration of Battery Energy Storage Systems (BESS) as part of a proposed microgrid created tension and divided some in the community. Some community members were reluctant to offer control of their BESS to a third party who would have the necessary technical knowledge and experience. The interviewee from the Tasmanian feasibility study also stated that the lack of a clear business model that could provide affordable electricity for consumers as well as benefits for the utilities is the major barrier. He stated, "*There is not a clear idea about what exactly the business model that can be suitable for this community....and that was part of our job actually to study and have a look at different business models to see which one is cost effective for customers as well as the utility.*"

The interviewees also referred to lack of funding, access to capital, high upfront capital cost, providing a compelling case to finance companies, and securing investment from third parties as significant barriers to the project. Most of the projects funded by the RRCRF were in small remote communities, with around 1-2 MW of solar and 2-3MWh of storage. However, the interviewee stated the projected return on investment in these microgrid projects is small compared to the amount of capital and effort needed to operate microgrids.

### 4.3.3 Social

The major social barriers interviewees identified are trust, energy literacy, employee/community member churn, and community expectations.

A low level of trust existed between local communities and the energy retailers and energy network providers. A factor identified that can further affect trust and overall engagement efforts is the level of energy literacy within the community. Where this has been perceived to be lower, it is more challenging to communicate the benefits of the projects and address doubts and reservations.

Gaining trust from the community can also be challenged by “consultation fatigue,” where some people have already been interviewed multiple times by researchers or government agencies. This is owing to being located in areas previously affected by extreme weather events. The result is that some individuals from the community can get frustrated with continually contributing their time without seeing any positive outcomes or change. Countering this barrier through careful relationship building and getting support from the local community energy groups was well understood by the interviewees to counter this barrier. Trust can also be affected by project stakeholders failing to understand the community’s needs and requirements while providing insufficient information to help them make informed decisions. In particular, by communicating all the possible outcomes for households regarding costs and reliability. One interviewee stated that the industry creates many assumptions about end users’ expectations (i.e., the community) that are not always accurate.

The RRCRF funding was targeted at communities that were either remote or rural, but there was considerable variability across the communities in terms of previous engagement on issues relating to sustainability and energy. Some communities had previously been involved in sustainability initiatives for as much as a decade and were thought by interviewees to have high energy literacy among sections of the community.

Other towns did not have the same experience and were perceived to have more variable energy literacy.

From the interviews, it was found that remote communities in both Western Australia and the Northern Territory had a particularly low awareness of solar and energy storage concepts and technologies. One of the interviewees undertaking feasibility studies for these communities stated that when surveying 10% of households about their electricity, energy efficiency, affordability, and renewable energy resources, none in the community knew what the term 'renewable energy' meant. However, the interviewees generally found that all the communities began with a 'low-to-no' understanding of microgrids. Major engagement strategies were required to explain the concept, often repeatedly. The interviewees were conscious that a lack of understanding of what a microgrid was and the technologies that were part of this could lead to communities developing fears and resistance to the feasibility project and its outcome.

As stated by interviewees, high employee churn has also disrupted their business operations, and the trend is more pronounced in Western Australia and Northern Territory, as compared to the national average (ABS, 2022). For remote areas in these states, changes in leadership within the community groups also slowed progress due to the need to re-establish relationships, regain commitment from the management team, and re-secure the social license to undertake microgrid feasibility for the communities. The interviewee involved in one of the remote region communities stated: *"The next biggest thing for me was the constant changeover of people in leadership roles within these communities. So, just multiple changes of CEOs (Chief Executive Officers) within a two year period. In any community that had a CEO, I saw a CEO come and go. So...it means that I had to start from square one with the relationship and getting them on board, and getting that social license and buy-in."* A lack of a formal governance model or organisation structure also made it more difficult for the project teams to engage sufficiently with some communities.

### 4.3.4 Technical

As discussed earlier in microgrid definitions, a defined boundary and islanding ability are key microgrid characteristics. The interviews highlighted a clear difference between communities regarding the ease of determining a boundary and ascertaining their suitability for islanding as part of their microgrid feasibilities. For communities on a radial network with a single connection point, it was more straightforward to identify the boundary and islandability of a potential microgrid. However, defining a boundary was far more complex for other communities due to the electricity network topography (e.g., being within a meshed electricity network) and community perception of which parts of their town and surrounding settlements should be included within the microgrid. This also raised questions of equity and inclusion among project team members when discussing boundary options with community members.

Data from multiple sources was needed to undertake the detailed feasibility study for community microgrids required by the RRCRF funding program. The data and analytical framework from one feasibility project show this complexity (see Figure 22).

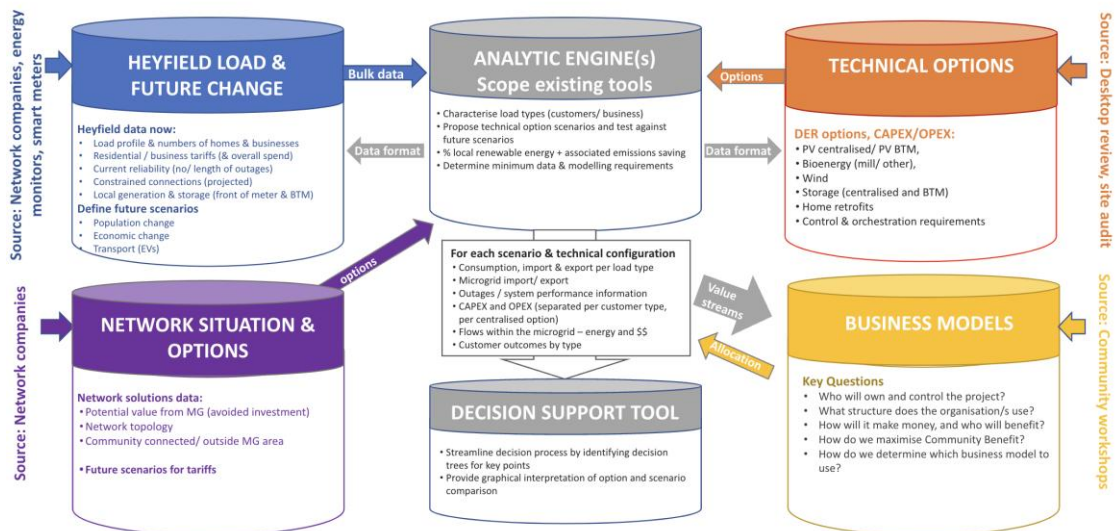


Figure 22 Overall analytics framework from the microgrid feasibility project (Langham et al., 2021).

The analytics framework conceptualises the different types, sources, and data flow required for the feasibility study communities (Langham et al., 2021).

The interviewees also highlighted the challenge of accessing data from the electricity distribution network companies as a significant barrier. Some experienced delays in gaining access to the data, which impacted the timelines of the feasibility analysis of the different projects. For the remote communities that relied on diesel generators and prepay energy meters, this issue was more basic because the data on how and when community members used energy simply weren't available. To address this, interviewees obtained the total power card expenditure for the entire community (usually paid for with cash) from the local shop owners to understand consumption at the aggregated level. Generic load profiles also had to be developed using sources in the academic literature due to an inability to obtain these for the communities in question due to this lack of data.

Another major challenge identified by the interviewees was identifying and selecting the most appropriate technologies and products available on the market for the community microgrid. Besides fulfilling community requirements and the ability to align with their region's decarbonisation targets, the teams also had to consider the various procurement considerations and challenges (such as availability of the product, estimated delivery times, handling practices, contracting, and operational practices and training). Supply chain issues challenged multiple projects caused by labour shortages (more acute in remote areas), high demand, and structural factors that have arisen during the COVID-19 pandemic and continue to persist.

Community acceptance of certain technologies also provided a challenge. Some community members were reluctant to install residential-scale battery energy storage systems on their premises due to perceived fire risks. However, this was mitigated by specifying a larger community-scale battery on public or private land.

Collecting energy consumption and generation data was critical in understanding the microgrid proposition for the various microgrid feasibility projects. With all the communities in rural or remote areas, smart meter data was not always available or sufficient. This meant the deployment of additional energy monitoring devices was required, which relied upon cellular networks to transmit the data. Rural and remote areas often have limited cellular coverage, which can hamper data collection, whether gathered from meter readings or energy monitoring. The interviewees experienced this issue of inconsistent or incomplete data sets resulting from connectivity issues in their projects. An interviewee stated, *“One of the major barriers there is the network connectivity, so they have 3G, they don't have 4G, and that was a challenge for us to do the smart meters connection and read from the smart meters as well as to do the digital twin”*. One project mitigated this risk by asking their vendor to redesign smart meters suitable for low connectivity and agricultural loads.

The need for local balancing of the demand and supply of electricity was also considered a challenge for most projects, particularly for remote communities not connected to the main grid. These communities could not export excess electricity to the main grid, so dealing with surplus electricity was highlighted as a major issue. For some communities, hosting capacity limits have already been enacted in the areas by distribution networks. Utilities manage the amount of electricity being exported by distributed solar PV while ensuring that frequency and voltage imbalances are addressed. When the supply of locally generated electricity exceeds the local demand, the community still cannot export the excess electricity due to hosting limits in place. This also highlighted the importance of storage, demand flexibility, diversity of loads and generation, and energy sharing.

#### 4.3.5 Legal

Ultimately, any microgrid defined as feasible will need to be delivered, owned, or operated by a legally defined organisation or organisations. The reservations of the

community members on how profit sharing would work and ownership of the assets (and who bears the risks) were considered significant barriers for many of the project stakeholders. An interviewee involved in the project in NT stated that:

*“It's quite daunting to think of all the challenges we're still yet to face, but I think the big one will be that there's really no regulatory pathway at the moment that would allow a community-owned asset to easily move through the steps of having a project designed, developed and receiving a revenue contract and then connected.”*

The interviewees highlighted land acquisition and site selection issues for installing solar systems and batteries as one of the most significant barriers to the microgrid feasibility studies. One of the interviewees explained that the selected site is on land owned by three families. It took approximately nine months to finalise the location, which was more prolonged and resource intensive than expected. Another interviewee also stated that securing suitable land was the most significant barrier. They said, *“Selecting a site...that's the biggest barrier by far. Because where the community would like to have a site isn't necessarily good (for a microgrid). There's...who owns the land, and the preferred site was actually Crown Land. And for various reasons, Crown Land is quite difficult to put a solar farm on. Another barrier is it needs to be close enough to a large enough transmission line”*. The challenge here is finding willing landowners to negotiate with while ensuring that the land is suitable for the solar and battery systems (i.e., at low risk from extreme weather effects such as fires and floods, and with suitable orientation for the solar).

The grant application and contracting process were also identified as the most formidable challenge for the projects, particularly where the community organisation was the lead. The resources needed to make a grant application submission and then undertake the contracting process when successful were found to be time-consuming and frustrating for smaller, not-for-profit organisations. An interviewee who was a part of a community energy group stated that:

*“For a community group like ourselves, the biggest challenge is the grant writing. So, there's a lot of people going for a limited number of grants, you've got to have somebody in the group who really understands what a good grant application looks like and how do you back it up.”*

#### 4.3.6 Limitations of PESTEL framework

The authors have observed a noteworthy aspect about categorising barriers within the studied framework. Specifically, certain barriers exhibit characteristics that align with multiple categories simultaneously. For instance, the challenge associated with site selection manifests elements that could be classified under social, technical, and legal barriers. This inherent complexity presents a limitation within the framework, a phenomenon duly acknowledged in the relevant literature (Yüksel, 2012). Despite this limitation, the authors have deliberately attempted to categorise these barriers as accurately as possible”.

The table below summarises the microgrid barriers from the existing literature and compares them with the research findings under the PESTEL framework.

Table 8 Summarising microgrid barriers from the existing literature and Australian feasibility studies

Categories	Barriers from literature	Barriers from this study
Political	<ul style="list-style-type: none"> <li>• <b>Lack of appropriate regulatory framework</b></li> <li>• Lack of clear policy initiatives</li> <li>• Increased involvement of political actors in the project</li> <li>• Lack of inclusion of microgrids in national energy policy</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Lack of appropriate regulatory framework</b></li> <li>• Restrictions due to COVID-19 Pandemic</li> </ul>
Economic	<ul style="list-style-type: none"> <li>• <b>Lack of funding and access to finance</b></li> <li>• High-cost network augmentation</li> <li>• High-cost grid safety and protection schemes</li> <li>• High cost of ensuring grid stability and bidirectional flow of power</li> <li>• <b>Absence of a clear business model and project ownership structure</b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Lack of clear business model and ownership structure</b></li> <li>• <b>Lack of funding and financial returns</b></li> </ul>
Social	<ul style="list-style-type: none"> <li>• Ensuring equity in revenue distribution (community ownership models)</li> <li>• <b>Trust building among stakeholders</b></li> <li>• Varying perceptions of the community toward renewable energy projects</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Engagement with the community:</b></li> <li>• <b>Lack of energy literacy</b></li> <li>• Constant changing over of people in the management role</li> </ul>
Technical	<ul style="list-style-type: none"> <li>• <b>Enabling islanding mode</b></li> <li>• <b>Ensuring voltage and frequency balance</b></li> <li>• Integration of various renewable energy technologies</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Identifying the microgrid boundary and islanding ability</b></li> <li>• Lack of access to network and customer data</li> <li>• Appropriate technology selection</li> <li>• Network connectivity issues</li> <li>• <b>Local demand and supply balancing</b></li> </ul>
Environmental	<ul style="list-style-type: none"> <li>• Ensuring proper reuse and recycling of technologies at the end of life</li> </ul>	
Legal	<ul style="list-style-type: none"> <li>• <b>Lack of legislation, particularly for smaller-scale microgrids</b></li> <li>• Delays in local government approvals and permits.</li> <li>• Lack of suitable legal experts</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Legal structures that define ownership</b></li> <li>• Acquisition of land and site</li> <li>• Contracting complexity for community organisations</li> </ul>

## 5. Discussion

### 5.1 Definitions that come with limitations

Multiple definitions for microgrids exist, but a few have emerged as preferred among researchers and industry. The variety of definitions indicates the growing popularity of microgrids as a potential local energy solution and the relatively early stage of the microgrid market. The word cloud shows that even experts and professionals directly involved in microgrid feasibility projects perceive them slightly differently, which will be influenced by the context of their experience and the projects they are involved with.

Government agencies are also using broad definitions to avoid restricting the number of technical configurations and commercial models that may be considered. However, applying the term 'microgrid' so broadly can confuse the concept. This could result in ambiguity and inconsistency within academic and policy dialogues, leading to misdirecting future research, funding programs, and policies. It could also seed confusion within communities where such feasibilities are being undertaken and where the concept of a microgrid must be carefully communicated.

### 5.2 Barriers that need both international and national approaches

The PESTEL framework can enable a clearer understanding of the diverse nature of the barriers encountered by microgrid feasibility projects. A number of the barriers hindering the future deployment of microgrids globally are also being experienced in Australian feasibility studies. A significant barrier identified from the interviews (and chiming with what was found in the international literature) was the lack of a fit-for-purpose regulatory and policy framework for microgrids. In addition, uncertainty remains among the projects interviewed and within the literature around the most suitable business models due to uncertainty over future costs and revenues.

Barriers such as lack of mobile network connectivity for monitoring devices, the legal complexities of land ownership and acquisition, and workforce issues associated with high employee churn were found to be characteristic of the Australian microgrid studies (and especially acute for remote areas).

Due to the complexity of the feasibilities and innovative approaches encouraged by the government funding program, the projects were typically delivered over multiple years. While this would have been beneficial from a technical delivery perspective, sustaining community interest over such a long period was challenging.

As the various projects conclude, many are aware of the difficulty of securing funding for their recommended local energy solutions and bridging the gap between feasibility and implementation. While Australia's new emerging microgrid funding programs are welcome, it is unclear how many RRCRF-funded projects and their communities will successfully access them.

Addressing these barriers will be essential for designing future microgrid policies and programs in Australia and internationally. It can also inform best practices for microgrid feasibility studies to ensure the most suitable local energy solutions are prescribed for remote and rural communities.

### 5.3 Grant-funded feasibility studies can stimulate microgrid activity

The RRCRF program considerably increased microgrid project activity in Australia, resulting in 36 feasibility projects in all states and territories over five years. It also brought together multiple stakeholders from industry, local businesses, community organisations, energy utilities, technology companies, research groups, and governments. This highlighted the ability of such a program to initiate collaboration and interactions between these different actors. A formal platform for sharing knowledge between projects of the RRCRF funding program did not exist, so this paper has

attempted to pool the learnings through a qualitative research approach. It would be advantageous for future grant programs to seek to formalise independent interagency knowledge sharing in advance, helping to support peer-to-peer learning and the transmission of knowledge between projects and programs for optimal outcomes.

#### 5.4 Strengthening drivers will require urgent action on policy soon

Our findings highlight a still nascent microgrid market in Australia, but with growing interest and capability, built through increased collaboration between various actors. This has been helped by a targeted funding program focusing on microgrid feasibilities for remote and rural communities. Four categories of drivers (Security; Reliability and Resilience; Economic; and Social) have been behind growing microgrid interest worldwide and they look likely to continue playing a strengthening role in Australia as well.

However, as mentioned in our analysis of the barriers, the lack of a suitable regulatory framework for microgrids persists in Australia, as with other international jurisdictions. Building on insights from the growing number of funded microgrid-related projects in Australia, a major governmental review to examine this persisting issue would be a positive first step. This would consider the policy reforms needed to help remote and rural communities' access reliable, affordable, clean energy, of which microgrids are just one potential solution. In addition, a national strategy that presents a vision and the resources needed to support local energy solutions (including but not limited to microgrids) for remote and regional communities could help bridge this gap.

## 6. Conclusion

Microgrids are being considered as solutions for communities seeking improved energy reliability and resilience, economic and environmental benefits, and maximisation of

locally generated renewable energy use. In Australia, significant government funding is being provided to projects undertaking microgrid feasibilities for rural and remote communities. This research explored the attitudes and experiences of those involved in 25 microgrid feasibility projects funded by a national government program in Australia. Through a thematic analysis approach based on (n=19) interviews (covering 25 of the 36 grant funding recipients and representing 70 of the 110 communities), their perceptions of microgrids and the barriers these projects have encountered were gathered and examined. Word cloud analysis was used to understand how those involved in each feasibility project interpreted the microgrid concept, whereas the PESTEL framework was used to code the barriers. Resilience was found to be a particularly strong driver for microgrids in Australia, while microgrids are expected to have a critical future role as part (islanded or not) of the electricity network. A lack of national policy framework for microgrids was identified as a major barrier that would hamper their implementation.

Given the current immaturity of the market, funding for microgrids and other local energy solution feasibilities and pilots remains critical. The research shows that funding programs such as the RRCRF can successfully increase microgrid activity at a national level. However, this must be combined with a coherent national policy framework for microgrids that can improve energy outcomes for communities. This includes tackling issues that are particularly challenging for rural and remote areas but are not exclusively energy related, such as those associated with mobile network connectivity, land ownership, and the workforce. This can be accelerated by enhanced knowledge sharing between agencies and among the growing number of projects receiving funding for microgrid feasibilities and pilots. If communities in rural and remote areas are truly to benefit from microgrids, such a coordinated and multifaceted approach will be needed.

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## 7. References

- A. Mohammed, S. S. Refaat, S. Bayhan, & H. Abu-Rub. (2019). AC Microgrid Control and Management Strategies: Evaluation and Review. *IEEE Power Electronics Magazine*, 6(2), 18–31. <https://doi.org/10.1109/MPEL.2019.2910292>.
- ABS. (2022). *Job mobility*. <https://www.abs.gov.au/statistics/labour/jobs/job-mobility/latest-release>
- ABS. (2023). *Australian Bureau of Statistics*. <https://www.abs.gov.au/>
- AEMC. (2022). *Energy System*. <https://www.aemc.gov.au/energy-system/electricity>
- AEMC. (2023). *National Electricity Market*. <https://www.aemc.gov.au/energy-system/electricity/electricity-system/NEM>
- Agarwal, M., & Mittal, A. (2011). Micro Grid Tehcniological Activities Across The Globe: A Review. *International Journal of Research and Reviews in Applied Sciences (IJRRAS)*, 7(2), 147–152.
- Ajaz, W., & Bernell, D. (2021). Microgrids and the transition toward decentralized energy systems in the United States: A Multi-Level Perspective. *Energy Policy*, 149(October 2020), 112094. <https://doi.org/10.1016/j.enpol.2020.112094>
- ARENA. (2022). *Off grid systems*. <https://arena.gov.au/renewable-energy/off-grid/>
- ARENA. (2023a). *Australian Renewable Energy Agency*. <https://arena.gov.au/>
- ARENA. (2023b). *Regional Microgrids Funding*. <https://arena.gov.au/funding/rmp/>
- B. Richter, E. Mengelkamp, & C. Weinhardt. (2019). Vote for your energy: a market mechanism for local energy markets based on the consumers' preferences. *16th International Conference on the European Energy Market (EEM)*, 1–6. <https://doi.org/doi:10.1109/EEM.2019.8916544>.

- Basak, P., Chowdhury, S., Halder Nee Dey, S., & Chowdhury, S. P. (2012). A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid. *Renewable and Sustainable Energy Reviews*, 16(8), 5545–5556. <https://doi.org/10.1016/j.rser.2012.05.043>
- Bebic, J. (2011). Power system planning: Emerging practices suitable for evaluating the impact of high-penetration photovoltaics. *Renewable Energy Grid Integration: Technical Performance and Requirements*, February, 141–170.
- Benjamin J.A.Walker, Wiersma, B., & Bailey, E. (2014). Community benefits, framing and the social acceptance of offshore wind farms: An experimental study in England. *Energy Research and Social Science*, 3, 46–54.
- Brummer, V. (2018). Community energy – benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces. *Renewable and Sustainable Energy Reviews*, 94(June), 187–196. <https://doi.org/10.1016/j.rser.2018.06.013>
- C. Echave, D. Ceh, A. B. and J. S.-T. (2019). An Ecosystemic Approach for Energy Transition in the Mediterranean Region,. *1st International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED)*, 1–5. <https://doi.org/10.1109/SyNERGY-MED.2019.8764107>.
- Cagnano, A., De Tuglie, E., & Mancarella, P. (2020). Microgrids: Overview and guidelines for practical implementations and operation. *Applied Energy*, 258(October 2019), 114039. <https://doi.org/10.1016/j.apenergy.2019.114039>
- CEFC. (2023). *Renewables*. <https://www.cefc.com.au/>
- CIGRE Working Group C.22. (2015). *Microgrids 1, Engineering, Economics, & Experience*.

- Clean Energy Council. (2019). *Clean Energy Australia Report*.  
<https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2019.pdf>
- Council, A. E. (2022). *CSIRO does the maths: RE + Integration*.  
<https://www.energycouncil.com.au/analysis/csiro-does-the-maths-re-integration/#:~:text=It projects that the levelized,between %2440 and %2459%2FMWh.>
- Coy, D., Malekpour, S., Saeri, A. K., & Dargaville, R. (2021). Rethinking community empowerment in the energy transformation: A critical review of the definitions, drivers and outcomes. *Energy Research and Social Science*, 72(December 2020), 101871.  
<https://doi.org/10.1016/j.erss.2020.101871>
- Denholm, P., O'Connell, M., Brinkman, G., & Jorgenson, J. (2015). Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart (NREL/TP-6A20-65023). *Technical Report, November*, 46.
- Department of Climate Change, Energy, the Environment, and W. (2022). *Regional and Remote Communities Reliability Fund*. <https://www.energy.gov.au/government-priorities/energy-programs/regional-and-remote-communities-reliability-fund>
- Dwyer, F. R., & Tanner, J. F. (2002). *Business marketing: Connecting strategy, relationships, and learning*. McGraw-Hill.
- Ekistica. (2018). *Lessons from the fringes: Australian fringe-of-grid projects in ARENA's portfolio*. June, 1–14.
- Energy.gov.au. (2022). *Energy Supply*. <https://www.energy.gov.au/government-priorities/energy-supply/#:~:text=Most of our electricity is,homes for heating and cooking.>
- Farrelly, M. A., & Tawfik, S. (2020). Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renewable and Sustainable Energy Reviews*, 117(October 2019), 109491. <https://doi.org/10.1016/j.rser.2019.109491>

- Feng, W., Jin, M., Liu, X., Bao, Y., Marnay, C., Yao, C., & Yu, J. (2018). A review of microgrid development in the United States – A decade of progress on policies, demonstrations, controls, and software tools. *Applied Energy*, 228, 1656–1668. <https://doi.org/10.1016/j.apenergy.2018.06.096>
- Freeman Julie, & Hancock Linda. (2017). Energy and communication infrastructure for disaster resilience in rural and regional Australia. *Regional Studies*, 51(6), 933–944. <https://doi.org/10.1080/00343404.2016.1146403>
- Golpîra, H., & Bevrani, H. (2019). Microgrids impact on power system frequency response. *Energy Procedia*, 156(September 2018), 417–424. <https://doi.org/10.1016/j.egypro.2018.11.097>
- Grisales-Noreña, L. F., Cortés-Caicedo, B., Montoya, O. D., Hernández, J. C., & Alcalá, G. (2023). A battery energy management system to improve the financial, technical, and environmental indicators of Colombian urban and rural networks. *Journal of Energy Storage*, 65(February), 107199. <https://doi.org/10.1016/j.est.2023.107199>
- Guerrero M. Josep, Juan C. Vasquez, Mehdi Savaghebi, E. G. Carrasco, & Teodorescu, R. (2013). Modeling, Analysis, and Design of Stationary Reference Frame Droop Controlled Parallel Three-Phase Voltage Source Inverters. *IEEE Transactions on Industrial Electronics*, 60(4), 1271–1280. <https://doi.org/10.1109/ICPE.2011.5944601>
- Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PLoS ONE*, 15(5), 1–17. <https://doi.org/10.1371/journal.pone.0232076>
- Gui, E. M., Diesendorf, M., & MacGill, I. (2017). Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renewable and Sustainable Energy Reviews*, 72(November 2016), 1355–1365. <https://doi.org/10.1016/j.rser.2016.10.047>

- Guibentif, T. M. M., & Vuille, F. (2022). Prospects and barriers for microgrids in Switzerland. *Energy Strategy Reviews*, 39, 100776. <https://doi.org/10.1016/j.esr.2021.100776>
- Hadjidemetriou, L., L. Zacharia, E. Kyriakides, B. Azzopardi, S. Azzopardi, R. Mikalauskiene, S. Al-Agtash, M. Al-hashem, A. Tsolakis, & D. Ioannidis. (2018). Design factors for developing a university campus microgrid. *IEEE International Energy Conference (ENERGYCON)*, 1–6. <https://doi.org/10.1109/ENERGYCON.2018.8398791>.
- Hanna, R., Ghonima, M., Kleissl, J., Tynan, G., & Victor, D. G. (2017). Evaluating business models for microgrids: Interactions of technology and policy. *Energy Policy*, 103(January), 47–61. <https://doi.org/10.1016/j.enpol.2017.01.010>
- Hatziargyriou, N. (2013). *Microgrids: Architectures and Control*. John Wiley and Sons.
- Hicks, J., & Ison, N. (2011). Community-owned renewable energy (CRE): Opportunities for rural Australia. *Rural Society*, 20(3), 244–255. <https://doi.org/10.5172/rsj.20.3.244>
- Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and Sustainable Energy Reviews*, 90(September 2017), 402–411. <https://doi.org/10.1016/j.rser.2018.03.040>
- IEA, IRENA, UNSD, WB, W. (2019). The energy progress report SDG7: The energy progress report. *IEA, IRENA, UNSD, WB, WHO (2019), Tracking SDG 7: The Energy Progress Report 2019, Washington DC*, 176.
- IPCC Report. (2021). *IPCC Report Key Findings*. United Nations. <https://www.un.org/en/climatechange/science/key-findings>
- Jiayi, H., Chuanwen, J., & Rong, X. (2008). A review on distributed energy resources and MicroGrid. *Renewable and Sustainable Energy Reviews*, 12(9), 2472–2483. <https://doi.org/10.1016/j.rser.2007.06.004>
- Kabalci, E. (2018). An islanded hybrid microgrid design with decentralized DC and AC subgrid controllers. *Energy*, 153, 185–199. <https://doi.org/10.1016/j.energy.2018.04.060>

- Katiraei, F., Iravani, M. R., & Lehn, P. (2004). Micro-grid autonomous operation during and subsequent to islanding process. *2004 IEEE Power Engineering Society General Meeting*, 2(1), 2175. <https://doi.org/10.1109/pes.2004.1373266>
- Kojima, Y. (n.d.). *Operation Result of the Hachinohe Microgrid Demonstration Project*. 1–18.
- Langham, E., Rutovitz, J., Smith, H., & Dwyer, S. (2021). *My Town Microgrid Conceptual Data and Analytical Framework*.
- Lasseter, R., Akhil, A., Marnay, C., Stephens, J., Dagle, J., Guttromson, R., & Meliopoulos A. (2002). The CERTS microgrid concept. *White Paper for Transmission Reliability Program, Office of Power Technologies, US Department o*, 2(3), 30f Energy,.
- Ilindala, M., Siddiqui, A., Venkataramanan, G., & Marnay, C. (2007). Localized aggregation of diverse energy sources for rural electrification using microgrids. *Journal of Energy Engineering*, 133(3), 121–131.
- Lu, X., Bahramirad, S., Wang, J., & Chen, C. (2015a). Bronzeville Community Microgrids: A Reliable, Resilient and Sustainable Solution for Integrated Energy Management with Distribution Systems. *Electricity Journal*, 28(10), 29–42. <https://doi.org/10.1016/j.tej.2015.11.009>
- Lu, X., Bahramirad, S., Wang, J., & Chen, C. (2015b). *Microgrids: A Reliable , Resilient*. 28(10).
- Lu, X., Wang, J., & Guo, L. (2016). Using microgrids to enhance energy security and resilience. *Electricity Journal*, 29(10), 8–15. <https://doi.org/10.1016/j.tej.2016.11.013>
- Lukas Weber. (1997). Some reflections on barriers to the efficient use of energy. *Energy Policy*, 25(10), 833–835.
- Madureira, A. G. (2010). *Coordinated and optimized voltage management of distribution networks with multi-microgrids*. Universidade do Porto (Portugal)).

- Marnay, C., & Giri Venkataramanan. (2006). *Microgrids in the Evolving Electricity Generation and Delivery Infrastructure*.
- Marnay, C., Venkataramanan, G., Stadler, M., Siddiqui, A. S., Firestone, R., & Chandran, B. (2008). Optimal technology selection and operation of commercial-building microgrids. *IEEE Transactions on Power Systems*, 23(3), 975–982. <https://doi.org/10.1109/TPWRS.2008.922654>
- Martin-Martínez, F., Sánchez-Miralles, A., & Rivier, M. (2016). A literature review of Microgrids: A functional layer based classification. *Renewable and Sustainable Energy Reviews*, 62, 1133–1153. <https://doi.org/10.1016/j.rser.2016.05.025>
- Meje, K. C., Bokopane, L., & Kusakana, K. (2020). Microgrids control strategies: A survey of available literature. *2020 8th International Conference on Smart Grid and Clean Energy Technologies, ICSGCE 2020, 2020*, 167–173. <https://doi.org/10.1109/ICSGCE49177.2020.9275651>
- Meteorology, B. of. (2022). *Special Climate Statement 75 – Australia ’ s wettest November on record. February*.
- Newman, D. (2015). Right-Sizing the Grid: The Electric Grid is Prone to Massive Outages. Would Downsizing Improve its Performance? *Mechanical Engineering*, 137(1), 34–39.
- Niklas, S., Alexander, D., & Dwyer, S. (2022). Resilient Buildings and Distributed Energy: A Grassroots Community Response to the Climate Emergency. *Sustainability (Switzerland)*, 14(6). <https://doi.org/10.3390/su14063186>
- Olivares, D. E., Mehrizi-Sani, A., Etemadi, A. H., Cañizares, C. A., Iravani, R., Kazerani, M., Hajimiragha, A. H., Gomis-Bellmunt, O., Saeedifard, M., Palma-Behnke, R., Jiménez-Estévez, G. A., & Hatziargyriou, N. D. (2014). Trends in microgrid control. *IEEE Transactions on Smart Grid*, 5(4), 1905–1919. <https://doi.org/10.1109/TSG.2013.2295514>

- Onu, U. G., Zambroni de Souza, A. C., & Bonatto, B. D. (2023). Drivers of microgrid projects in developed and developing economies. *Utilities Policy*, 80(December 2022), 101487. <https://doi.org/10.1016/j.jup.2022.101487>
- Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.
- Perera, R. (2017). *The PESTLE analysis*. Nerdynaut.
- Perez-DeLaMora, D. A., Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. G. (2021). Roadmap on community-based microgrids deployment: An extensive review. *Energy Reports*, 7, 2883–2898. <https://doi.org/10.1016/j.egyr.2021.05.013>
- Pesin, M. (2017). *Winter Meeting U . S . Department of Energy Electricity Grid Research and Development*.
- Planas, E., Andreu, J., Gárate, J. I., Martínez de Alegría, I., & Ibarra, E. (2015). AC and DC technology in microgrids: A review. *Renewable and Sustainable Energy Reviews*, 43, 726–749. <https://doi.org/10.1016/j.rser.2014.11.067>
- Pullins, S. (2019). Why microgrids are becoming an important part of the energy infrastructure. *Electricity Journal*, 32(5), 17–21. <https://doi.org/10.1016/j.tej.2019.05.003>
- R. A. F. Ferreira, P. G. Barbosa, H. A. C. Braga, & A. A. Ferreira. (2013). Analysis of non-linear adaptive voltage droop control method applied to a grid connected DC microgrid. *Brazilian Power Electronics Conference*, 1067–1074. <https://doi.org/10.1109/COBEP.2013.6785247>.
- RACE for 2030. (2023). <https://racefor2030.com.au/>
- Regional and Remote Communities Reliability Fund Microgrid. (2021). <https://business.gov.au/grants-and-programs/regional-and-remote-communities-reliability-fund-microgrids#at-a-glance>

- Regulator, C. E. (2023). *Renewable Energy Target*.  
<https://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations>
- Rezkallah, M., Chandra, A., Singh, B., & Singh, S. (2019). Microgrid: Configurations, control and applications. *IEEE Transactions on Smart Grid*, 10(2), 1290–1302.  
<https://doi.org/10.1109/TSG.2017.2762349>
- Romankiewicz, J., Marnay, C., Zhou, N., & Qu, M. (2014). Lessons from international experience for China's microgrid demonstration program. *Energy Policy*, 67, 198–208.  
<https://doi.org/10.1016/j.enpol.2013.11.059>
- Shahidehpour, M., & Clair, J. F. (2012). A Functional Microgrid for Enhancing Reliability, Sustainability, and Energy Efficiency. *Electricity Journal*, 25(8), 21–28.  
<https://doi.org/10.1016/j.tej.2012.09.015>
- Soshinskaya, M., Crijns-Graus, W. H. J., Guerrero, J. M., & Vasquez, J. C. (2014). Microgrids: Experiences, barriers and success factors. In *Renewable and Sustainable Energy Reviews* (Vol. 40, pp. 659–672). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2014.07.198>
- Sovacool, B. K., Axsen, J., & Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research and Social Science*, 45(November 2017), 12–42.  
<https://doi.org/10.1016/j.erss.2018.07.007>
- Sovacool, B. K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: A synthesized approach. *Energy*, 36(8), 5343–5355.  
<https://doi.org/10.1016/j.energy.2011.06.043>
- Suman, G. K., Guerrero, J. M., & Roy, O. P. (2022). Stability of microgrid cluster with Diverse Energy Sources: A multi-objective solution using NSGA-II based controller. *Sustainable*

- Energy Technologies and Assessments*, 50(December 2021), 101834.  
<https://doi.org/10.1016/j.seta.2021.101834>
- Tao, L., Schwaegerl, C., Narayanan, S., & Zhang, J. H. (2011). From laboratory Microgrid to real markets Challenges and opportunities. *8th International Conference on Power Electronics - ECCE Asia: "Green World with Power Electronics", ICPE 2011-ECCE Asia*, 264–271. <https://doi.org/10.1109/ICPE.2011.5944600>
- Temene Hermann, D., Donatien, N., Konchou Franck Armel, T., & René, T. (2022). Techno-economic and environmental feasibility study with demand-side management of photovoltaic/wind/hydroelectricity/battery/diesel: A case study in Sub-Saharan Africa. *Energy Conversion and Management*, 258(March).  
<https://doi.org/10.1016/j.enconman.2022.115494>
- Ton, D. T., & Smith, M. A. (2012). The U.S. Department of Energy's Microgrid Initiative. *Electricity Journal*, 25(8), 84–94. <https://doi.org/10.1016/j.tej.2012.09.013>
- Ullah, S., Haidar, A. M. A., Hoole, P., Zen, H., & Ahfock, T. (2020). The current state of Distributed Renewable Generation, challenges of interconnection and opportunities for energy conversion based DC microgrids. *Journal of Cleaner Production*, 273, 122777.  
<https://doi.org/10.1016/j.jclepro.2020.122777>
- Unamuno, E., & Barrena, J. A. (2015). Hybrid ac/dc microgrids - Part I: Review and classification of topologies. *Renewable and Sustainable Energy Reviews*, 52, 1251–1259. <https://doi.org/10.1016/j.rser.2015.07.194>
- Ustun, T. S., Ozansoy, C., & Zayegh, A. (2011). Recent developments in microgrids and example cases around the world - A review. *Renewable and Sustainable Energy Reviews*, 15(8), 4030–4041. <https://doi.org/10.1016/j.rser.2011.07.033>

- Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663. <https://doi.org/10.1016/j.enpol.2009.05.055>
- Wang, C., Yan, J., Marnay, C., Djilali, N., Dahlquist, E., Wu, J., & Jia, H. (2018). Distributed Energy and Microgrids (DEM). *Applied Energy*, 210, 685–689. <https://doi.org/10.1016/j.apenergy.2017.11.059>
- Wei, P., & Chen, W. (2019). Microgrid in China: A review in the perspective of application. *Energy Procedia*, 158, 6601–6606. <https://doi.org/10.1016/j.egypro.2019.01.059>
- Wouters, C. (2015). Towards a regulatory framework for microgrids - The Singapore experience. *Sustainable Cities and Society*, 15, 22–32. <https://doi.org/10.1016/j.scs.2014.10.007>
- Wu, L., Ortmeyer, T., & Li, J. (2016). The community microgrid distribution system of the future. *Electricity Journal*, 29(10), 16–21. <https://doi.org/10.1016/j.tej.2016.11.008>
- Y. Wu, Y. Wu, J. M. Guerrero, J. C. Vasquez, & J. Li. (2019). AC Microgrid Small-Signal Modeling: Hierarchical Control Structure Challenges and Solutions. *IEEE Electrification Magazine*, 7(4), 81–88. <https://doi.org/10.1109/MELE.2019.2943980>.
- Yüksel, I. (2012). Developing a Multi-Criteria Decision Making Model for PESTEL Analysis. *International Journal of Business and Management*, 7(24), 52–66. <https://doi.org/10.5539/ijbm.v7n24p52>

# Chapter 5

## Embracing Complexity: Microgrids and Community Engagement in Australia

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## Chapter 5. Embracing complexity: Microgrids and community engagement in Australia.

### 5.1 Introduction to the chapter

This chapter presents the published article titled "Embracing Complexity: Microgrids and Community Engagement in Australia," which has been published in *Energy Research & Social Science*. This chapter directly addresses research questions 2 and 3 about: What community engagement strategies facilitate the planning and implementation of microgrids in diverse Australian communities, and what will be the implications of including local communities in the decision-making process? (see Chapter 1, section 1.6)

By examining the practices, challenges, and strategies employed in community engagement, this study provides valuable insights into how community involvement influences the success of microgrid feasibility studies and their broader adoption. The research investigates nineteen organisations that received government funding to conduct microgrid feasibility studies across ninety communities in Australia, utilising a Community-Based Participatory Research (CBPR) framework (a part of integrative conceptual framework stated in Chapter 3, section 3.4). The findings highlight key engagement challenges, such as inadequate funding, low energy literacy, and engagement fatigue, and propose strategies for overcoming these barriers. This chapter contributes to the growing body of literature on the social dimensions of energy transitions, offering practical recommendations for community engagement practitioners, policymakers, and microgrid developers.

## Abstract:

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.

## Keywords

Microgrids; Community engagement; Rural and remote communities; Energy transition; Community Based Participatory Research; Australia.

## 1. Introduction

The energy transition represents a complex process, with multiple systems such as technical, social, institutional and cultural working in an overlapping manner (Geels & Schot, 2007; Kunneke, 2008; Unruh GC, 2000). Energy transitions do not only involve a substitution of technology but also include shifts in user practices, regulations, and public attitudes (Owens S & Driffill L., 2008; Smith A & Stirling A, 2010). 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 (T. von Wirth et al., 2018). 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 (Wüstenhagen et al., 2007). Thus, deep community engagement and effective consultation can increase the chances for the social acceptance of renewable energy technologies (Wüstenhagen et al., 2007).

Community engagement is considered a critical factor for the successful implementation of renewable energy projects, regardless of scale or type (Waisman, H., Bataille, C., Winkler & et al., 2019; Walker G & Cass N, 2007; Warren CR & McFadyen M, 2010). This is due to its ability to develop a sense of partnership between the different actors while building trust with the local community (Vargas et al., 2019; Walker et al., 2010; Warbroek & Hoppe, 2017). 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 (Mirakyan & De Guio, 2013; S. Wirth, 2014). Previous research has also revealed that those renewable energy projects where the community is more actively engaged tend to be more successful (Walker G & Cass N, 2007; Warren CR & McFadyen M, 2010).

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 (Chalaye et al., 2023; Hirsch et al., 2018; Perez-DeLaMora et al., 2021; Ritchie et al., 2019). While renewable microgrids for communities in Australia are still nascent, considerable government funding has been made available to accelerate their adoption (Farrelly & Tawfik, 2020; Tahir et al., 2024). 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 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 (Miller et al., 2013). In particular, a thorough understanding of community practices, thinking, and behaviour is vital in the overall process (Moloney et al., 2010; Sovacool et al., 2017). However, the absence of active community involvement in a renewable energy project can lead to diminished trust that the transition can deliver public benefits (Ransan-Cooper et al., 2022). Thus, social acceptance plays a crucial role in the successful deployment of renewable energy projects (Devine-Wright, 2007). Social acceptance requires a comprehensive understanding of community concerns, preferences, and reservations (Batel et al., 2013; Vaidya & Mayer, 2016). Social acceptance can be achieved by engaging with the communities and understanding their perceptions of the technology (Milani et al., 2024).

Although there is no agreed definition of community engagement (Batidzirai et al., 2021; Brummer, 2018; van de Grift et al., 2020), it is generally defined as a process in which people work collaboratively, through inspired learning, to create and realise the visions of the future (Moore et al., 2016). It can vary in each case as community energy projects exhibit substantial diversity depending on scale, technological variation, social organisation levels, and project purpose (Walker & Simcock, 2012). The subsequent level of community engagement can also range widely from passive consultation to active involvement and collaboration (McGookin et al., 2021). 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 (Komendantova et al., 2018; Simplilearn, 2023). However, such approaches have been criticised as being unable to capture the community's actual

needs (Batidzirai et al., 2021). Conversely, other projects may follow a bottom-up community engagement approach (Međugorac & Schuitema, 2023; van Summeren et al., 2020), considering the project site as the source of grassroots innovation while devising strategies according to the community's desires and needs (Seyfang & Smith, 2007). 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 (Lee et al., 2016; Seyfang et al., 2013).

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 (Chapman & Pambudi, 2018; Ernst et al., 2018; Kowalski et al., 2009; McKenna et al., 2018; Volken et al., 2018). Interview techniques are varied and may be structured or semi-structured, conducted in person, or undertaken remotely by telephone or online (Simoes et al., 2019; Tahir et al., 2024). Workshops and focus groups can increase community participation while providing a better understanding of community attitudes, preferences, and vision (Ernst et al., 2018). 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 (G. Busch, 2017; Dubinsky et al., 2019; Krzywoszynska et al., 2016). Interactive strategies, such as scenario generation (Li & Pye, 2018) and the serious game approach (Flood et al., 2018), 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 (Eklund et al., 2024; Hirsch et al., 2018). This is due to their ability to operate independently of the main grid while integrating locally generated renewable energy resources (Wright et al., 2024).

They have also been cited as being able to provide other advantages such as energy security (Lu et al., 2016; Onu et al., 2023), energy reliability (Wu et al., 2016), remote power supply (Soshinskaya et al., 2014), and resiliency against natural disasters (Pullins, 2019; Warneryd & Karltorp, 2022). Microgrids have also been found to improve power quality, reduce frequency fluctuations and voltage imbalance, and improve power losses (Golpîra & Bevrani, 2019; Suman et al., 2022).

The literature reveals multiple definitions for the term 'microgrid' (Basak et al., 2012; Jiayi et al., 2008; Ustun et al., 2011; Yu et al., 2018). 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"* (Olivares et al., 2014; Perez-DeLaMora et al., 2021; Ton & Smith, 2012).

The existing literature on microgrids predominantly focuses on its techno-economic aspects (Ustun et al., 2011). For instance, researchers have presented in-depth analysis of the economic aspects of microgrids (Clarke et al., 2020; Hotaling et al., 2021; Mengelkamp et al., 2019; Prevedello & Werth, 2021; Wang et al., 2020). Technical aspects of microgrids have also been discussed in detail. For instance, (Hossain et al., 2019) have discussed the challenges and barriers of using converter-based microgrids, (Ullah et al., 2020) have elaborated the protection scenarios in the microgrid operations, (Planas et al., 2015) have thoroughly reviewed technical aspects of DC and AC microgrids. (El-Bidairi et al., 2020; Golpîra & Bevrani, 2019; Suman et al., 2022) have reviewed dynamic frequency behaviour in microgrids. The role of energy storage in microgrids has been discussed by (Abu-Sharkh et al., 2006; Zhou et al., 2018), while (Aziz et al., 2020; Heidari et al., 2017; Planas et al., 2013) have reviewed control strategies and control mechanisms. Microgrid design optimization and optimization of energy management systems have also been thoroughly evaluated (Su & Wang, 2012; Yamashita et al., 2020; Zachar & Daoutidis, 2015). Researchers have also highlighted

the three major categories of microgrids: AC (alternating current) microgrids (A. Mohammed et al., 2019; Y. Wu et al., 2019), DC (direct current) microgrids (Kabalci, 2018; Meje et al., 2020; R. A. F. Ferreira et al., 2013), and hybrid microgrid (which integrates both AC and DC power sources, storage, and loads) (Meje et al., 2020; Rezkallah et al., 2019; Temene Hermann et al., 2022; Unamuno & Barrena, 2015).

While there has been significant research previously undertaken on the techno-economic aspects of microgrids (Meje et al., 2020; Shahbazitabar et al., 2021), some have highlighted that the social aspects of microgrids require more exploration (Chalaye et al., 2023; Muttaqee et al., 2023; Valencia et al., 2021). 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 (Scovell et al., 2024), wind farms (Mhairi Aitken, 2010), community batteries (Csereklyei et al., 2024), hydrogen production (Scovell & Walton, 2024), and geothermal technology (Dowd et al., 2011). 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 below (see Table 9):

*Table 9 Summary of relevant articles*

#	Author	Details	Methods
1	(Kaczmariski, 2022)	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	(Hotaling et al., 2021)	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	(Perez-DeLaMora et al., 2021)	Identified, evaluated, and summarised trends relating to the social (as well as the technical) aspects of community-based microgrid deployments.	Systematic review
4	(Muttaqee et al., 2023)	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	(Akinyele et al., 2018)	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	(Kirchhoff et al., 2016)	Identified the success factors for microgrid implementation based on case studies from Germany, highlighting the significance of success factors such as the active participation of stakeholders.	Literature review, case study approach, meta-study with thematic analysis
7	(Warneryd et al., 2020)	A desk-based review of community microgrids worldwide to examine the institutional reasons behind their growing adoption.	Literature review
8	(Onu et al., 2023)	Reviewed microgrids implementation in developing and developed countries while understanding the drivers and impacts of microgrid projects	Literature review, case study approach
9	(Ruggiero et al., 2014)	Explored the role of stakeholders through interviews (n=41) in influencing the development of community energy projects across Europe.	Literature review, structured interviews
10	(Wu et al., 2016)	A discussion article covering the key characteristics of community microgrids, the social benefits, as well	Literature review

		as the required technical solutions and methodologies.	
11	(Gui et al., 2017)	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	(Alvial-Palavicino et al., 2011)	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	(Warneryd & Karltorp, 2022)	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	(Syed & Morrison, 2021)	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	(Chalaye et al., 2023)	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	(Eklund et al., 2023)	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	(Farrelly & Tawfik, 2020)	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	(Tahir et al., 2024)	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
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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.

### 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 (see Figure 13).

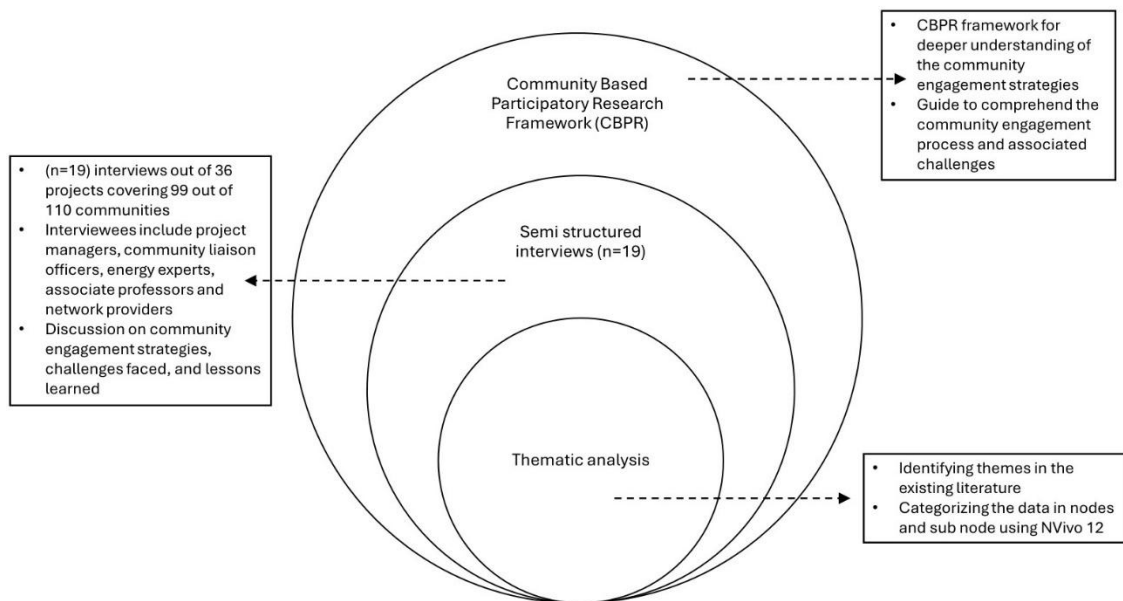


Figure 23 A conceptual overview of the methodology

### 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 (Sherry R. Arnstein, 1969), the Public Engagement Onion model (Oxford, 2023), Multi-Level Perspective (MLP) (Ajaz & Bernell, 2021; Smith A & Stirling A, 2010), the Behavioural Developmental Model (BDM) (Petit, 2019) and Social Capital Theory (Eklund et al., 2023).

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 (Kwon et al., 2018; Tremblay et al., 2017). 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 (Jami & Walsh, 2017; Jamshidi et al., 2014). In addition, it is successful at achieving a common knowledge production process where multiple stakeholders are involved (Israel, 2019; Lavery et al., 2010; Ward et al., 2018).

### 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 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 minutes. 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 (Sovacool et al., 2018). 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 the table below:

*Table 10 Details of the interviewees*

<b>Interview ee</b>	<b>Role</b>	<b>Organisation type</b>	<b>Community characteristics</b>	<b>No. of communiti es</b>	<b>Combined population of the community served</b>	<b>State</b>
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 Officer	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 Officer	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

### 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 (BG & Strauss AL, 1967).

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.

## 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. Figure 24 summarises the thematic analysis process, followed by the explanation in the following section.

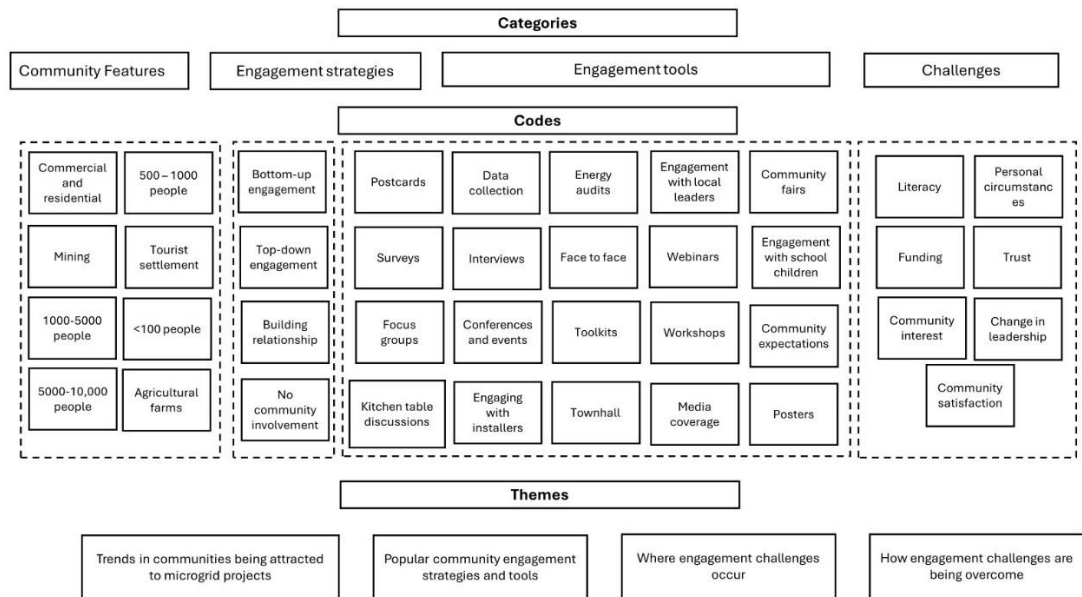
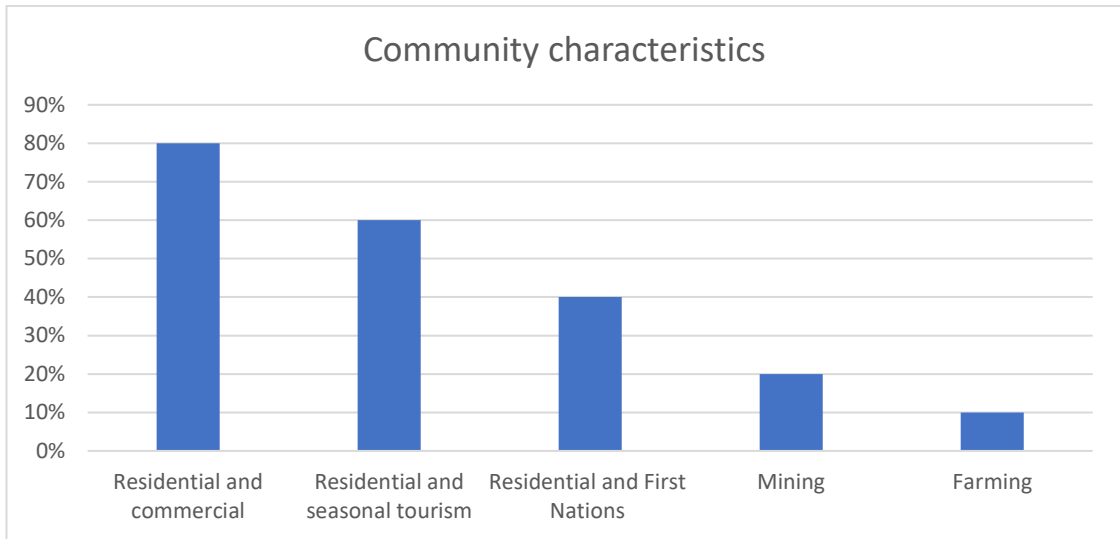


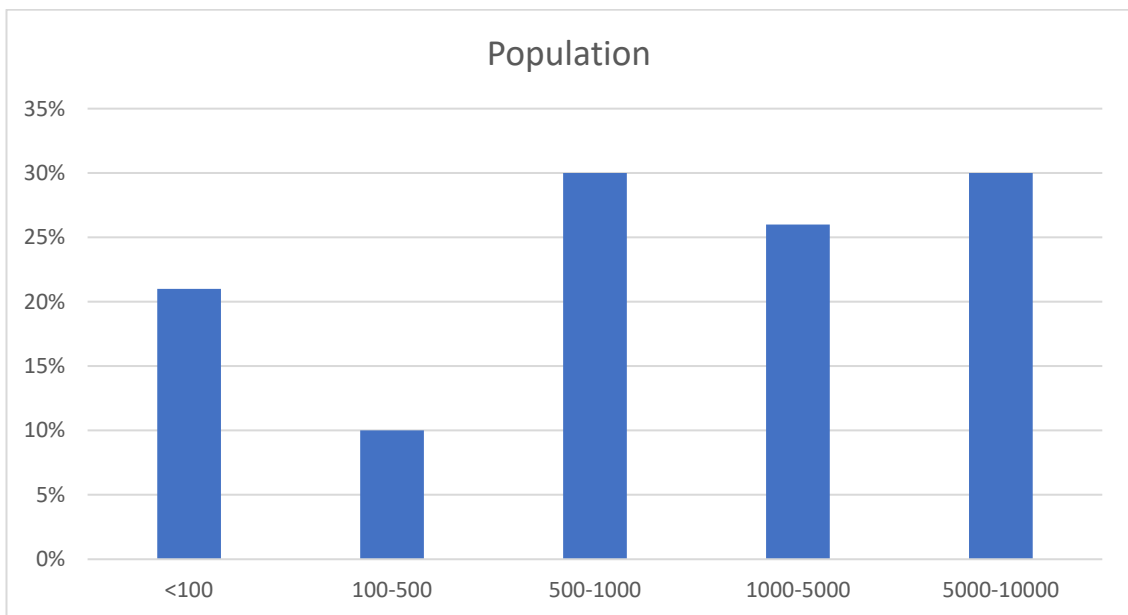
Figure 24 Summary of Thematic Analysis Process

## 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 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. Figures 25 and 26 below show the community characteristics and population breakdown of those involved in the feasibility studies.



*Figure 25 Community characteristics of those involved in the microgrid feasibility studies*



*Figure 26 Population of the communities involved in the microgrid 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).

Figure 27 shows the percentage of projects employing the different engagement approaches.

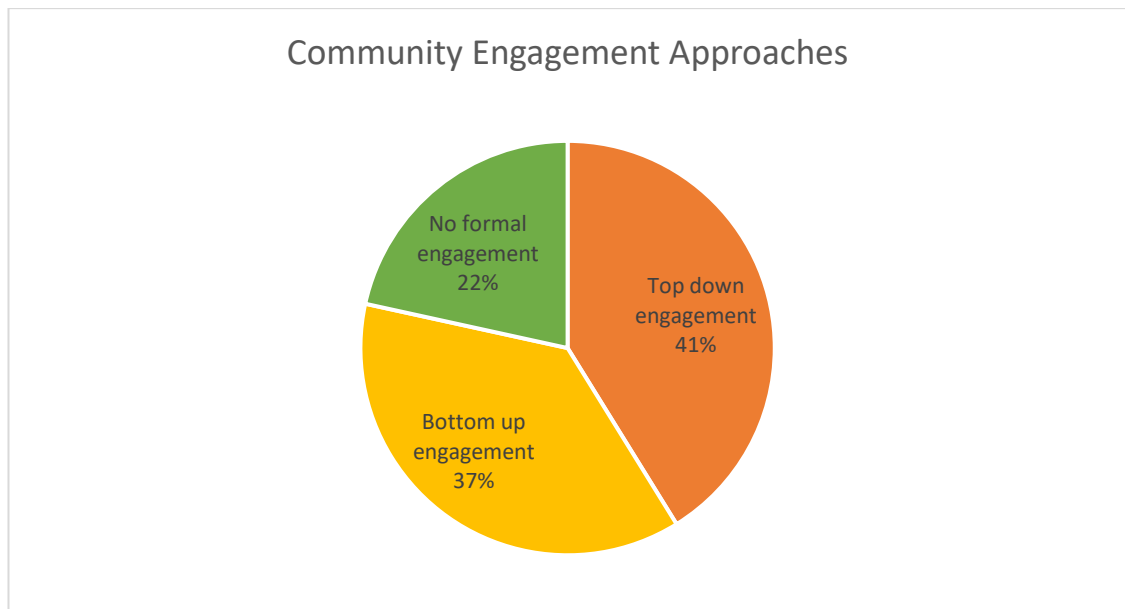


Figure 27 Community engagement approaches used by the microgrid feasibility studies

## 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"*.

### 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. Some interviewees noted that a division would appear in the group where having to 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 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 (Barbara Misztal, 1996; H. Busch & Hansen, 2021). 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 (Israel, 2019). 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.

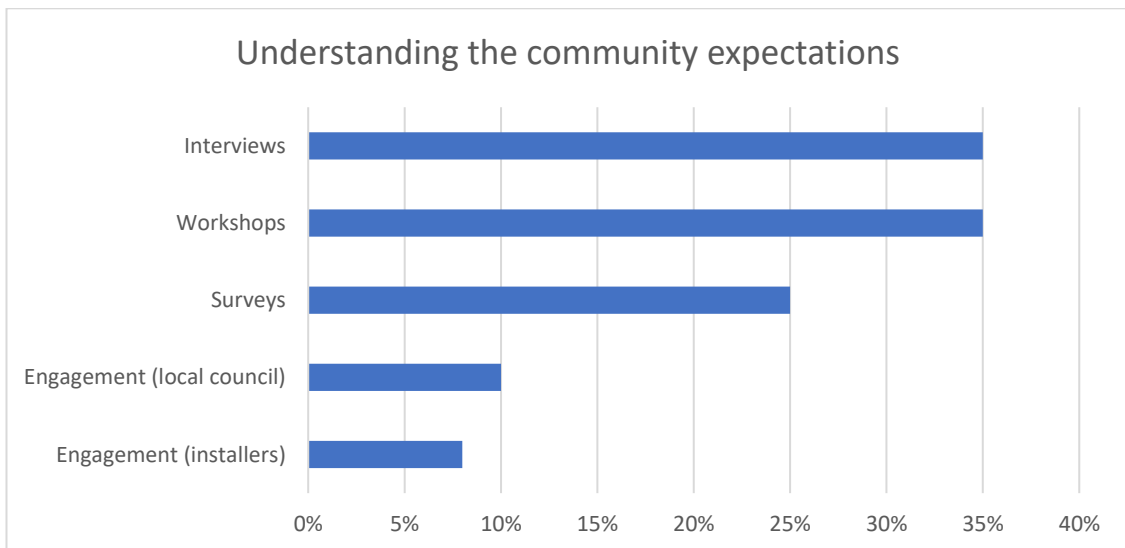
An interviewee commented: *“We conducted a vision workshop at the beginning of the project, understanding the community's vision for the project and their expectations. Subsequently, we formulated our research plan according to the expectations”.*

Table 11 describes the different community engagement tools that were used in the microgrid feasibility studies to understand community expectations. Figure 28 shows the percentage of projects that used those tools, with interviews and workshops the commonly employed.

*Table 11 Community engagement tools used by the microgrid feasibility studies.*

<b>Type</b>	<b>Description</b>
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 specific setting to discuss issues as a small group.
Workshops	Brings community members and stakeholders together in a specific setting to work intensively and interactively on issues as a small group.
Stakeholder engagement	Systematic identification 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.



*Figure 28 Engagement tools used in the microgrid feasibility studies for understanding community expectations.*

Interviewees were also asked what expectations existed in their communities should a microgrid prove feasible. The bar graph (Figure 29) below shows how from the thematic analysis of their answers, resilience and reliability were among the most held expectations, followed by decarbonisation and affordability.

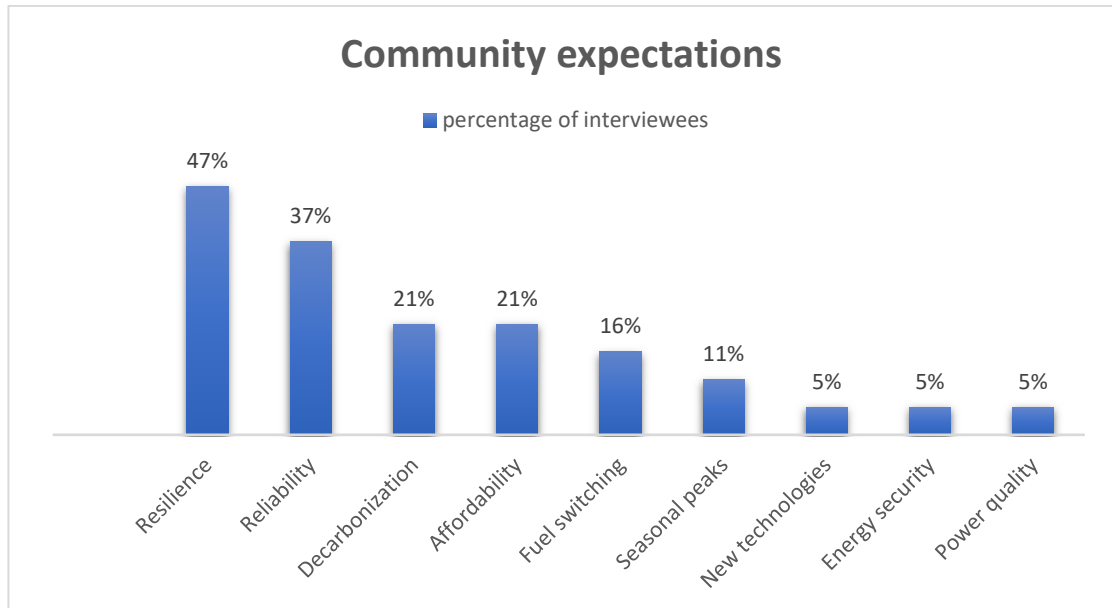


Figure 29 Community Expectations

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.”*

The engagement strategies used by the microgrid feasibility projects for codesigning the research are presented in Figure 30. 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.

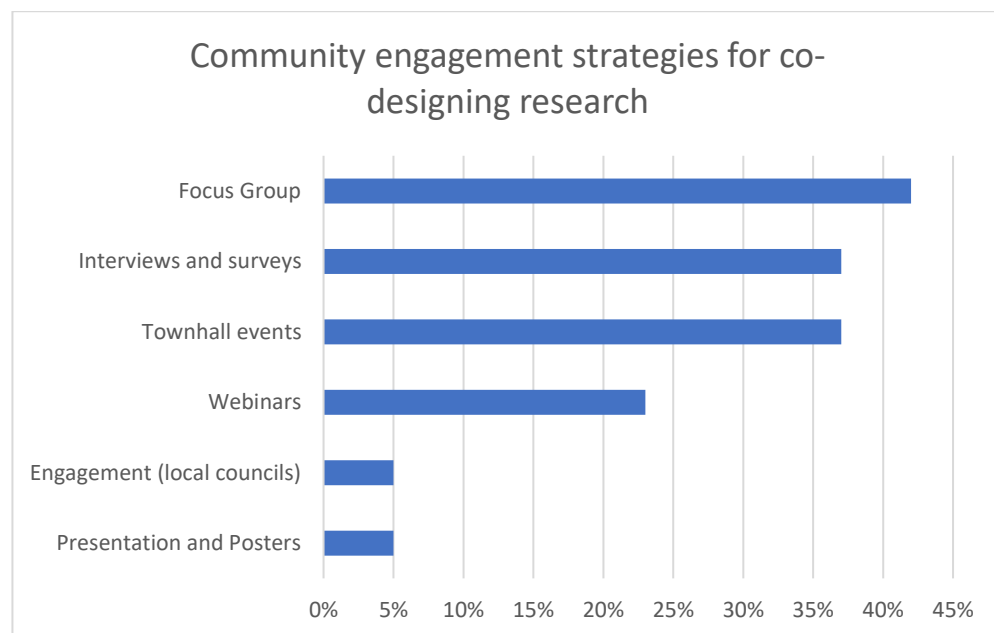


Figure 30 Community engagement strategies for co-design used in the microgrid feasibility studies.

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 (Sovacool et al., 2018). 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 less than 10% of the projects interviewed couldn't access any data, relying on power bill estimations instead.

Table 12 describes the different data sources that were used by the microgrid feasibility studies and Figure 31 shows the percentage of those projects that relied on the different sources.

*Table 12 Data sources used by the microgrid feasibility studies and their definitions*

<b>Type</b>	<b>Description</b>
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 defined intervals.
Energy monitoring devices	Two-way communication monitoring device that measures how much electricity is consumed and generated at defined 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 specific 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.

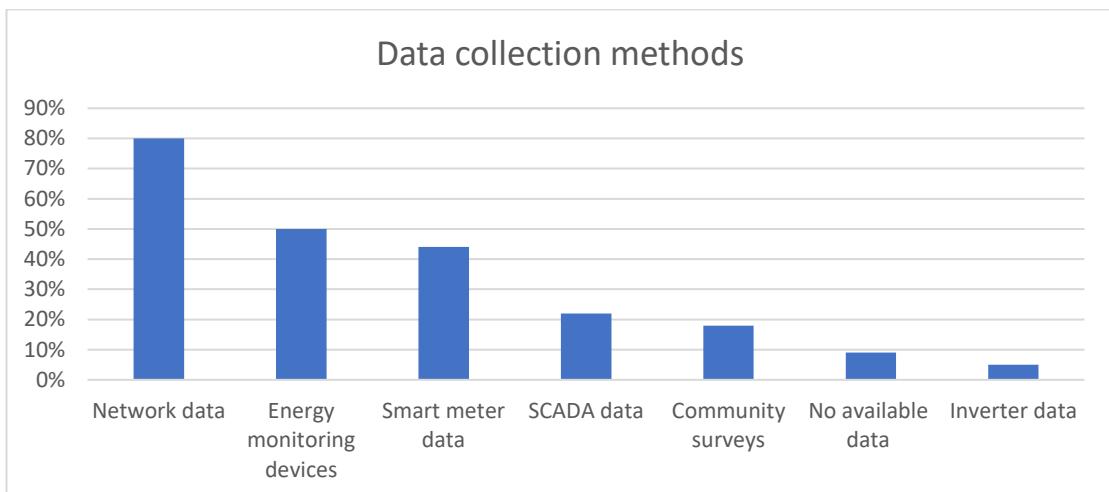


Figure 31 Data collection methods used in the microgrid feasibility projects

#### 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 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 13. Figure 32 shows the percentage of projects that relied on the different dissemination methods:

*Table 13 Dissemination methods used in the microgrid feasibility projects and their target audience*

<b>Dissemination method</b>	<b>Definition</b>	<b>Target Audience</b>
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 specific 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.
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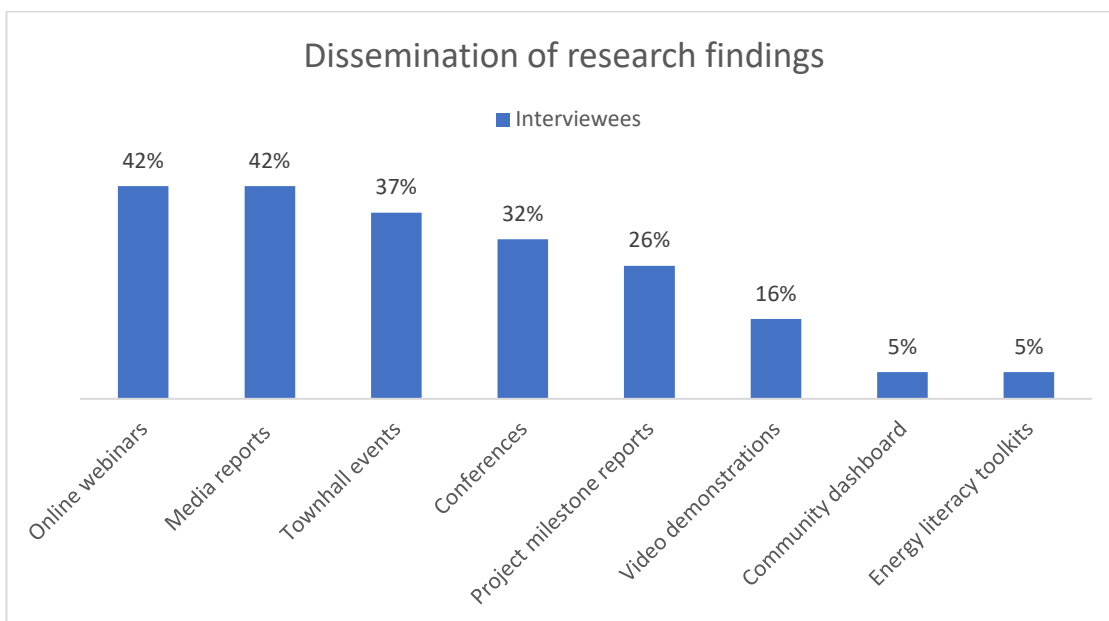


Figure 32 Dissemination methods used in the microgrid feasibility projects

#### 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 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 (see Fig 33).

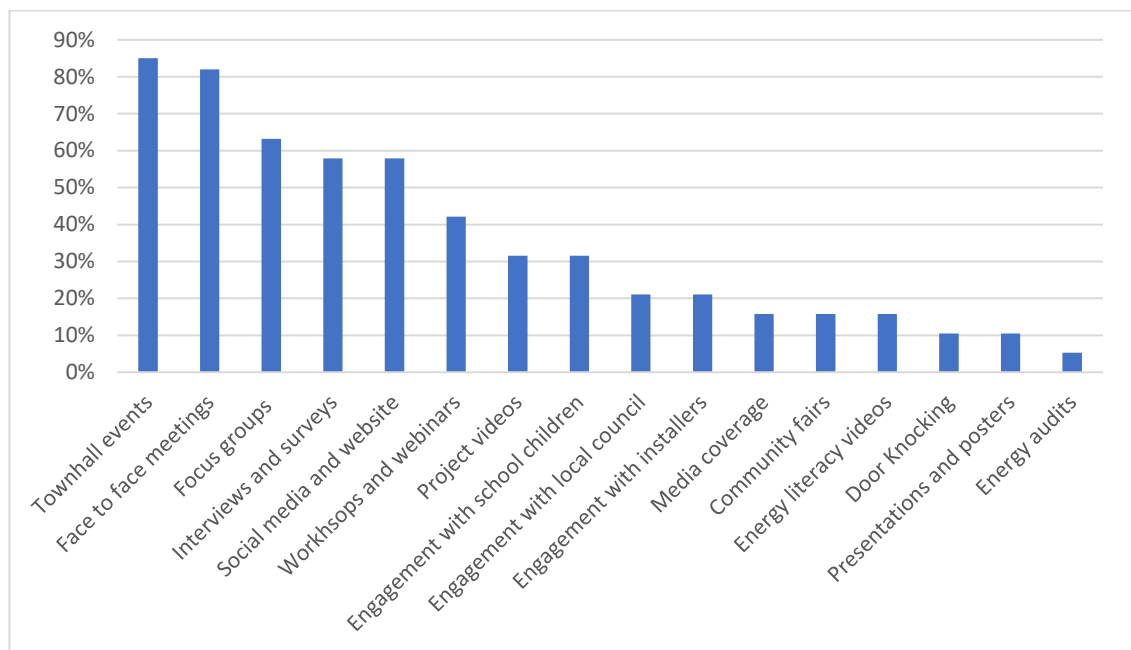


Figure 33 Summary of community engagement strategies used in the feasibility studies

## 4.12 Summary of the results

Table 14 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).

*Table 14 Heat map of the CBPR stages undertaken by each interviewee in their community engagement*

CBPR stage/ Interviewees <sup>2</sup>	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

<sup>2</sup> 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.

9	Red	White	White	Red	White	Red	White
10	Dark Red	Dark Red	Dark Red	Dark Red	Dark Red	Dark Red	Dark Red
11	Red	White	White	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	Red	White	White	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	Red	Red	White	Red	White	Red	White
18	Red	Red	White	Red	White	Red	Red
19	Red	White	White	Red	White	White	White

## 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 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 mean 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 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 projects. 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 were 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. The 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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### **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.

## 7. References

- A. Mohammed, S. S. Refaat, S. Bayhan, & H. Abu-Rub. (2019). AC Microgrid Control and Management Strategies: Evaluation and Review. *IEEE Power Electronics Magazine*, 6(2), 18–31. <https://doi.org/10.1109/MPEL.2019.2910292>.
- Abu-Sharkh, S., Arnold, R. J., Kohler, J., Li, R., Markvart, T., Ross, J. N., Steemers, K., Wilson, P., & Yao, R. (2006). Can microgrids make a major contribution to UK energy supply? *Renewable and Sustainable Energy Reviews*, 10(2), 78–127. <https://doi.org/10.1016/j.rser.2004.09.013>
- Ajaz, W., & Bernell, D. (2021). Microgrids and the transition toward decentralized energy systems in the United States: A Multi-Level Perspective. *Energy Policy*, 149(October 2020), 112094. <https://doi.org/10.1016/j.enpol.2020.112094>

- Akinyele, D., Belikov, J., & Levron, Y. (2018). Challenges of Microgrids in Remote Communities: A STEEP Model Application. *Energies*, 11, 432. <https://doi.org/10.3390/en11020432>
- Alvial-Palavicino, C., Garrido-Echeverría, N., Jiménez-Estévez, G., Reyes, L., & Palma-Behnke, R. (2011). A methodology for community engagement in the introduction of renewable based smart microgrid. *Energy for Sustainable Development*, 15(3), 314–323. <https://doi.org/10.1016/j.esd.2011.06.007>
- Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., Mohammed, M. F., & Ramli, M. A. M. (2020). Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. *Energy*, 191. <https://doi.org/10.1016/j.energy.2019.116591>
- Barbara Misztal. (1996). *Trust in Modern Societies: The Search for the Bases of Social Order*. <https://www.wiley.com/en-au/Trust+in+Modern+Societies%3A+The+Search+for+the+Bases+of+Social+Order-p-9780745616346>
- Basak, P., Chowdhury, S., Halder Nee Dey, S., & Chowdhury, S. P. (2012). A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid. *Renewable and Sustainable Energy Reviews*, 16(8), 5545–5556. <https://doi.org/10.1016/j.rser.2012.05.043>
- Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infrastructures: A critical discussion. *Energy Policy*, 58, 1–5. <https://doi.org/10.1016/j.enpol.2013.03.018>
- Batidzirai, B., Trotter, P. A., Brophy, A., Stritzke, S., Moyo, A., Twesigye, P., Puranasamriddhi, A., & Madhlopa, A. (2021). Towards people-private-public partnerships: An integrated community engagement model for capturing energy access needs. *Energy Research and Social Science*, 74(February), 101975. <https://doi.org/10.1016/j.erss.2021.101975>

- BG, G., & Strauss AL. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*.
- Brummer, V. (2018). Community energy – benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces. *Renewable and Sustainable Energy Reviews*, 94(June), 187–196. <https://doi.org/10.1016/j.rser.2018.06.013>
- Busch, G. (2017). A spatial explicit scenario method to support participative regional land-use decisions regarding economic and ecological options of short rotation coppice (SRC) for renewable energy production on arable land: case study application for the Göttingen dist. *Energy, Sustainability and Society*, 7(1). <https://doi.org/10.1186/s13705-017-0105-4>
- Busch, H., & Hansen, T. (2021). Building communities in times of crisis - Impacts of the COVID-19 pandemic on the work of transition intermediaries in the energy sector. *Energy Research and Social Science*, 75(October 2020), 102020. <https://doi.org/10.1016/j.erss.2021.102020>
- Chalaye, P., Sturmberg, B., Ransan-Cooper, H., Lucas-Healey, K., Russell, A. W., Hendriks, J., Hansen, P., O'Neill, M., Crowfoot, W., & Shorten, P. (2023). Does site selection need to be democratized? A case study of grid-tied microgrids in Australia. *Energy Policy*, 183(April), 113854. <https://doi.org/10.1016/j.enpol.2023.113854>
- Chapman, A. J., & Pambudi, N. A. (2018). Strategic and user-driven transition scenarios: Toward a low carbon society, encompassing the issues of sustainability and societal equity in Japan. *Journal of Cleaner Production*, 172, 1014–1024. <https://doi.org/10.1016/j.jclepro.2017.10.225>
- Clarke, W. C., Brear, M. J., & Manzie, C. (2020). Control of an isolated microgrid using hierarchical economic model predictive control. *Applied Energy*, 280(October), 115960. <https://doi.org/10.1016/j.apenergy.2020.115960>

- Colvin, R. M., Witt, G. B., & Lacey, J. (2016). How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. *Energy Policy*, 98, 483–494. <https://doi.org/10.1016/j.enpol.2016.09.022>
- Csereklyei, Z., Dwyer, S., Kallies, A., & Economou, D. (2024). The role of community-scale batteries in the energy transition: Case studies from Australia's National Electricity Market. *Journal of Energy Storage*, 93. <https://doi.org/10.1016/j.est.2024.112277>
- Devine-Wright, P. (2007). Reconsidering public attitudes and public acceptance of renewable energy technologies : a critical review. *Architecture, Working Pa*(February), 1–15. [http://geography.exeter.ac.uk/beyond\\_nimbyism/deliverables/bn\\_wp1\\_4.pdf](http://geography.exeter.ac.uk/beyond_nimbyism/deliverables/bn_wp1_4.pdf)
- Dowd, A. M., Boughen, N., Ashworth, P., & Carr-Cornish, S. (2011). Geothermal technology in Australia: Investigating social acceptance. *Energy Policy*, 39(10), 6301–6307. <https://doi.org/10.1016/j.enpol.2011.07.029>
- Dubinsky, J., Baker-Jennings, E., Chernomordik, T., Main, D. S., & Karunanithi, A. T. (2019). Engaging a rural agricultural community in sustainability indicators and future scenario identification: case of San Luis Valley. *Environment, Development and Sustainability*, 21(1), 79–93. <https://doi.org/10.1007/s10668-017-0024-8>
- Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2023). Energy Research & Social Science Understanding the community in community microgrids: A conceptual framework for better decision-making. *Energy Research & Social Science*, 104(August), 103260. <https://doi.org/10.1016/j.erss.2023.103260>
- Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2024). Community microgrids: A decision framework integrating social capital with business models for improved resiliency. *Applied Energy*, 367. <https://doi.org/10.1016/j.apenergy.2024.123458>
- El-Bidairi, K. S., Nguyen, H. D., Mahmoud, T. S., Jayasinghe, S. D. G., & Guerrero, J. M. (2020). Optimal sizing of Battery Energy Storage Systems for dynamic frequency control

- in an islanded microgrid: A case study of Flinders Island, Australia. *Energy*, 195, 117059.  
<https://doi.org/10.1016/j.energy.2020.117059>
- Ernst, A., Biß, K. H., Shamon, H., Schumann, D., & Heinrichs, H. U. (2018). Benefits and challenges of participatory methods in qualitative energy scenario development. *Technological Forecasting and Social Change*, 127(September 2017), 245–257.  
<https://doi.org/10.1016/j.techfore.2017.09.026>
- Farrelly, M. A., & Tawfik, S. (2020). Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renewable and Sustainable Energy Reviews*, 117(October 2019), 109491. <https://doi.org/10.1016/j.rser.2019.109491>
- Flood, S., Craddock-Henry, N. A., Blackett, P., & Edwards, P. (2018). Adaptive and interactive climate futures: Systematic review of “serious games” for engagement and decision-making. *Environmental Research Letters*, 13(6). <https://doi.org/10.1088/1748-9326/aac1c6>
- Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, 36(3), 399–417. <https://doi.org/10.1016/j.respol.2007.01.003>
- Golpîra, H., & Bevrani, H. (2019). Microgrids impact on power system frequency response. *Energy Procedia*, 156(September 2018), 417–424.  
<https://doi.org/10.1016/j.egypro.2018.11.097>
- Gui, E. M., Diesendorf, M., & MacGill, I. (2017). Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renewable and Sustainable Energy Reviews*, 72(October 2016), 1355–1365.  
<https://doi.org/10.1016/j.rser.2016.10.047>
- Heidari, R., Seron, M. M., & Braslavsky, J. H. (2017). Ultimate boundedness and regions of attraction of frequency droop controlled microgrids with secondary control loops. *Automatica*, 81, 416–428. <https://doi.org/10.1016/j.automatica.2016.12.021>

- Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and Sustainable Energy Reviews*, 90(September 2017), 402–411. <https://doi.org/10.1016/j.rser.2018.03.040>
- Hossain, M. A., Pota, H. R., Hossain, M. J., & Blaabjerg, F. (2019). Evolution of microgrids with converter-interfaced generations: Challenges and opportunities. *International Journal of Electrical Power and Energy Systems*, 109(February), 160–186. <https://doi.org/10.1016/j.ijepes.2019.01.038>
- Hotaling, C., Bird, S., & Heintzelman, M. D. (2021). Willingness to pay for microgrids to enhance community resilience. *Energy Policy*, 154(March), 112248. <https://doi.org/10.1016/j.enpol.2021.112248>
- Israel, B. A. et al. (2019). Community-based participatory research. In *Urban Health* (pp. 272–282).
- Jami, A. A., & Walsh, P. R. (2017). From consultation to collaboration: A participatory framework for positive community engagement with wind energy projects in Ontario, Canada. *Energy Research and Social Science*, 27, 14–24. <https://doi.org/10.1016/j.erss.2017.02.007>
- Jamshidi, E., Morasae, E. K., Shahandeh, K., Majdzadeh, R., Seydali, E., Aramesh, K., & Abknar, N. L. (2014). Ethical considerations of community-based participatory research: Contextual underpinnings for developing countries. *International Journal of Preventive Medicine*, 5(10), 1328–1336.
- Jiayi, H., Chuanwen, J., & Rong, X. (2008). A review on distributed energy resources and MicroGrid. *Renewable and Sustainable Energy Reviews*, 12(9), 2472–2483. <https://doi.org/10.1016/j.rser.2007.06.004>
- Kabalci, E. (2018). An islanded hybrid microgrid design with decentralized DC and AC subgrid controllers. *Energy*, 153, 185–199. <https://doi.org/10.1016/j.energy.2018.04.060>

- Kaczmarek, J. I. (2022). Public support for community microgrid services. *Energy Economics*, 115. <https://doi.org/10.1016/j.eneco.2022.106344>
- Kirchhoff, H., Kebir, N., Neumann, K., Heller, P. W., & Strunz, K. (2016). Developing mutual success factors and their application to swarm electrification: microgrids with 100 % renewable energies in the Global South and Germany. *Journal of Cleaner Production*, 128, 190–200. <https://doi.org/10.1016/j.jclepro.2016.03.080>
- Komendantova, N., Riegler, M., & Neumueller, S. (2018). Of transitions and models: Community engagement, democracy, and empowerment in the Austrian energy transition. *Energy Research and Social Science*, 39(November 2017), 141–151. <https://doi.org/10.1016/j.erss.2017.10.031>
- Kowalski, K., Stagl, S., Madlener, R., & Omann, I. (2009). Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis. *European Journal of Operational Research*, 197(3), 1063–1074. <https://doi.org/10.1016/j.ejor.2007.12.049>
- Krzywoszynska, A., Buckley, A., Birch, H., Watson, M., Chiles, P., Mawyin, J., Holmes, H., & Gregson, N. (2016). Co-producing energy futures: impacts of participatory modelling. *Building Research and Information*, 44(7), 804–815. <https://doi.org/10.1080/09613218.2016.1211838>
- Kunneke, R. (2008). Institutional reform and technological practice, the case of electricity. *Ind Corp Change*, 17, 233–265.
- Kwon, S. C., Tandon, S. D., Islam, N., Riley, L., & Trinh-Shevrin, C. (2018). Applying a community-based participatory research framework to patient and family engagement in the development of patient-centered outcomes research and practice. *Translational Behavioral Medicine*, 8(5), 683–691. <https://doi.org/10.1093/tbm/ibx026>

- Lavery, J. V., Tinadana, P. O., Scott, T. W., Harrington, L. C., Ramsey, J. M., Ytuarte-Nuñez, C., & James, A. A. (2010). Towards a framework for community engagement in global health research. *Trends in Parasitology*, 26(6), 279–283. <https://doi.org/10.1016/j.pt.2010.02.009>
- Lee, S. J., Hoffman, G., & Harris, D. (2016). Community-Based Participatory Research (CBPR) needs assessment of parenting support programs for fathers. *Children and Youth Services Review*, 66, 76–84. <https://doi.org/10.1016/j.childyouth.2016.05.004>
- Li, F. G. N., & Pye, S. (2018). Uncertainty, politics, and technology: Expert perceptions on energy transitions in the United Kingdom. *Energy Research and Social Science*, 37(September 2017), 122–132. <https://doi.org/10.1016/j.erss.2017.10.003>
- Lu, X., Wang, J., & Guo, L. (2016). Using microgrids to enhance energy security and resilience. *Electricity Journal*, 29(10), 8–15. <https://doi.org/10.1016/j.tej.2016.11.013>
- McGookin, C., Ó Gallachóir, B., & Byrne, E. (2021). Participatory methods in energy system modelling and planning – A review. *Renewable and Sustainable Energy Reviews*, 151(July). <https://doi.org/10.1016/j.rser.2021.111504>
- McKenna, R., Bertsch, V., Mainzer, K., & Fichtner, W. (2018). Combining local preferences with multi-criteria decision analysis and linear optimization to develop feasible energy concepts in small communities. *European Journal of Operational Research*, 268(3), 1092–1110. <https://doi.org/10.1016/j.ejor.2018.01.036>
- Međugorac, V., & Schuitema, G. (2023). Why is bottom-up more acceptable than top-down? A study on collective psychological ownership and place-technology fit in the Irish Midlands. *Energy Research and Social Science*, 96(December 2022). <https://doi.org/10.1016/j.erss.2022.102924>
- Meje, K. C., Bokopane, L., & Kusakana, K. (2020). Microgrids control strategies: A survey of available literature. *2020 8th International Conference on Smart Grid and Clean Energy*

*Technologies, ICSGCE 2020, 2020, 167–173.*  
<https://doi.org/10.1109/ICSGCE49177.2020.9275651>

Mengelkamp, E., Diesing, J., & Weinhardt, C. (2019). Tracing local energy markets. *Tracing Local Energy Markets: A Literature Review.*, 61(2–3), 101–110.

Mhairi Aitken. (2010). Wind power and community benefits: Challenges and opportunities. *Energy Policy*, 38(10), 6066–6075. <https://doi.org/10.1016/j.enpol.2010.05.062>

Milani, A., Dessi, F., & Bonaiuto, M. (2024). A meta-analysis on the drivers and barriers to the social acceptance of renewable and sustainable energy technologies. *Energy Research and Social Science*, 114. <https://doi.org/10.1016/j.erss.2024.103624>

Miller, C. A., Alastair Iles, & Christopher F. Jones. (2013). The Social Dimensions of Energy Transitions. *Science as Culture*, 135–148.  
<https://doi.org/10.1080/09505431.2013.786989>

Mirakyan, A., & De Guio, R. (2013). Integrated energy planning in cities and territories: A review of methods and tools. *Renewable and Sustainable Energy Reviews*, 22, 289–297. <https://doi.org/10.1016/j.rser.2013.01.033>

Moloney, S., Horne, R. E., & Fien, J. (2010). Transitioning to low carbon communities-from behaviour change to systemic change: Lessons from Australia. *Energy Policy*, 38(12), 7614–7623. <https://doi.org/10.1016/j.enpol.2009.06.058>

Moore, T., Mcdonald, M., Mchugh-Dillon, H., & West, S. (2016). Community engagement A key strategy for improving outcomes for Australian families. Australian Institute of Family Studies. *Child Family Community Australia / Information Exchange*, 39.

Muttaqee, M., Furqan, M., & Boudet, H. (2023). Community response to microgrid development: Case studies from the U.S. *Energy Policy*, 181(December 2022), 113690. <https://doi.org/10.1016/j.enpol.2023.113690>

- Olivares, D. E., Mehrizi-Sani, A., Etemadi, A. H., Cañizares, C. A., Iravani, R., Kazerani, M., Hajimiragha, A. H., Gomis-Bellmunt, O., Saeedifard, M., Palma-Behnke, R., Jiménez-Estévez, G. A., & Hatziargyriou, N. D. (2014). Trends in microgrid control. *IEEE Transactions on Smart Grid*, 5(4), 1905–1919. <https://doi.org/10.1109/TSG.2013.2295514>
- Onu, U. G., Zambroni de Souza, A. C., & Bonatto, B. D. (2023). Drivers of microgrid projects in developed and developing economies. *Utilities Policy*, 80(December 2022), 101487. <https://doi.org/10.1016/j.jup.2022.101487>
- Owens S, & Driffill L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policy*, 36, 4412–4418.
- Oxford, U. of. (2023). *The Public Engagement Onion*. Mathematical, Physical, and Life Sciences Division. <https://www.mpls.ox.ac.uk/public-engagement/what-is-public-engagement/the-public-engagement-onion>
- Perez-DeLaMora, D. A., Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. G. (2021). Roadmap on community-based microgrids deployment: An extensive review. *Energy Reports*, 7, 2883–2898. <https://doi.org/10.1016/j.egyr.2021.05.013>
- Petit, V. (2019). The Behavioural drivers model: a conceptual framework for social and behaviour change programming. *UNICEF Middle East and North Africa Regional Office Amman: UNICEF*.
- Planas, E., Andreu, J., Gárate, J. I., Martínez de Alegría, I., & Ibarra, E. (2015). AC and DC technology in microgrids: A review. *Renewable and Sustainable Energy Reviews*, 43, 726–749. <https://doi.org/10.1016/j.rser.2014.11.067>
- Planas, E., Gil-De-Muro, A., Andreu, J., Kortabarria, I., & Martínez De Alegría, I. (2013). General aspects, hierarchical controls and droop methods in microgrids: A review.

- Renewable and Sustainable Energy Reviews*, 17, 147–159.  
<https://doi.org/10.1016/j.rser.2012.09.032>
- Prevedello, G., & Werth, A. (2021). The benefits of sharing in off-grid microgrids: A case study in the Philippines. *Applied Energy*, 303(August), 117605.  
<https://doi.org/10.1016/j.apenergy.2021.117605>
- Pullins, S. (2019). Why microgrids are becoming an important part of the energy infrastructure. *Electricity Journal*, 32(5), 17–21. <https://doi.org/10.1016/j.tej.2019.05.003>
- R. A. F. Ferreira, P. G. Barbosa, H. A. C. Braga, & A. A. Ferreira. (2013). Analysis of non-linear adaptive voltage droop control method applied to a grid connected DC microgrid. *Brazilian Power Electronics Conference*, 1067–1074.  
<https://doi.org/10.1109/COBEP.2013.6785247>.
- Ransan-Cooper, H., Shaw, M., Sturmberg, B. C. P., & Blackhall, L. (2022). Neighbourhood batteries in Australia: Anticipating questions of value conflict and (in)justice. *Energy Research and Social Science*, 90(June 2021).  
<https://doi.org/10.1016/j.erss.2022.102572>
- Rezkallah, M., Chandra, A., Singh, B., & Singh, S. (2019). Microgrid: Configurations, control and applications. *IEEE Transactions on Smart Grid*, 10(2), 1290–1302.  
<https://doi.org/10.1109/TSG.2017.2762349>
- Ritchie, H., Rosado, P., & Roser, M. (2019). *Access to Energy*. OurWorldInData.Org.  
<https://ourworldindata.org/energy-access>
- Ruggiero, S., Onkila, T., & Kuittinen, V. (2014). Realizing the social acceptance of community renewable energy: A process-outcome analysis of stakeholder influence. *Energy Research and Social Science*, 4(C), 53–63. <https://doi.org/10.1016/j.erss.2014.09.001>

- Scovell, M., McCrea, R., Walton, A., & Poruschi, L. (2024). Local acceptance of solar farms: The impact of energy narratives. *Renewable and Sustainable Energy Reviews*, 189. <https://doi.org/10.1016/j.rser.2023.114029>
- Scovell, M., & Walton, A. (2024). Blue or Green? Exploring Australian acceptance and beliefs about hydrogen production methods. *Journal of Cleaner Production*, 444. <https://doi.org/10.1016/j.jclepro.2024.141151>
- Seyfang, G., Park, J. J., & Smith, A. (2013). A thousand flowers blooming? An examination of community energy in the UK. *Energy Policy*, 61, 977–989. <https://doi.org/10.1016/j.enpol.2013.06.030>
- Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, 16(4), 584–603. <https://doi.org/10.1080/09644010701419121>
- Shahbazitabar, M., Abdi, H., Nourianfar, H., Anvari-Moghaddam, A., Mohammadi-Ivatloo, B., & Hatzigiorgiou, N. (2021). An introduction to microgrids, concepts, definition, and classifications. *Power Systems*, 3–16. [https://doi.org/10.1007/978-3-030-59750-4\\_1](https://doi.org/10.1007/978-3-030-59750-4_1)
- Sherry R. Arnstein. (1969). A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*, 35(4), 216–224. <https://doi.org/https://doi.org/10.1080/01944366908977225>
- Simoës, S. G., Dias, L., Gouveia, J. P., Seixas, J., De Miglio, R., Chiodi, A., Gargiulo, M., Long, G., & Giannakidis, G. (2019). InSmart – A methodology for combining modelling with stakeholder input towards EU cities decarbonisation. *Journal of Cleaner Production*, 231, 428–445. <https://doi.org/10.1016/j.jclepro.2019.05.143>
- Simplilearn. (2023). *Top Down Approach vs Bottom Up Approach: Understanding the Differences*. <https://www.simplilearn.com/top-down-approach-vs-bottom-up-approach-article#:~:text=The main difference between the,the development of detailed knowledge.>

- Smith A, & Stirling A. (2010). The politics of social–ecological resilience and sustainable socio-technical transitions. *Ecol Soc*, 15(1).  
<http://www.ecologyandsociety.org/%0Avol15/iss1/art11/>.
- Soshinskaya, M., Crijns-Graus, W. H. J., Guerrero, J. M., & Vasquez, J. C. (2014). Microgrids: Experiences, barriers and success factors. In *Renewable and Sustainable Energy Reviews* (Vol. 40, pp. 659–672). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2014.07.198>
- Sovacool, B. K., Axsen, J., & Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research and Social Science*, 45(November 2017), 12–42.  
<https://doi.org/10.1016/j.erss.2018.07.007>
- Sovacool, B. K., Kivimaa, P., Hielscher, S., & Jenkins, K. (2017). Vulnerability and resistance in the United Kingdom’s smart meter transition. *Energy Policy*, 109(August), 767–781.  
<https://doi.org/10.1016/j.enpol.2017.07.037>
- Su, W., & Wang, J. (2012). Energy Management Systems in Microgrid Operations. *Electricity Journal*, 25(8), 45–60. <https://doi.org/10.1016/j.tej.2012.09.010>
- Suman, G. K., Guerrero, J. M., & Roy, O. P. (2022). Stability of microgrid cluster with Diverse Energy Sources: A multi-objective solution using NSGA-II based controller. *Sustainable Energy Technologies and Assessments*, 50(December 2021), 101834.  
<https://doi.org/10.1016/j.seta.2021.101834>
- Syed, M. M., & Morrison, G. M. (2021). A rapid review on community connected microgrids. *Sustainability (Switzerland)*, 13(12). <https://doi.org/10.3390/su13126753>
- Tahir, F., Dwyer, S., & Kelly, S. (2024). Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program. *Energy Research and Social Science*, 109(July 2023), 103423. <https://doi.org/10.1016/j.erss.2024.103423>

- Temene Hermann, D., Donatien, N., Konchou Franck Armel, T., & René, T. (2022). Techno-economic and environmental feasibility study with demand-side management of photovoltaic/wind/hydroelectricity/battery/diesel: A case study in Sub-Saharan Africa. *Energy Conversion and Management*, 258(March). <https://doi.org/10.1016/j.enconman.2022.115494>
- Ton, D. T., & Smith, M. A. (2012). The U.S. Department of Energy's Microgrid Initiative. *Electricity Journal*, 25(8), 84–94. <https://doi.org/10.1016/j.tej.2012.09.013>
- Tremblay, M. C., Martin, D. H., Macaulay, A. C., & Pluye, P. (2017). Can we Build on Social Movement Theories to Develop and Improve Community-Based Participatory Research? A Framework Synthesis Review. *American Journal of Community Psychology*, 59(3–4), 333–362. <https://doi.org/10.1002/ajcp.12142>
- Ullah, S., Haidar, A. M. A., Hoole, P., Zen, H., & Ahfock, T. (2020). The current state of Distributed Renewable Generation, challenges of interconnection and opportunities for energy conversion based DC microgrids. *Journal of Cleaner Production*, 273, 122777. <https://doi.org/10.1016/j.jclepro.2020.122777>
- Unamuno, E., & Barrena, J. A. (2015). Hybrid ac/dc microgrids - Part I: Review and classification of topologies. *Renewable and Sustainable Energy Reviews*, 52, 1251–1259. <https://doi.org/10.1016/j.rser.2015.07.194>
- Unruh GC. (2000). Understanding carbon lock-in. *Energy Policy*, 28, 817–830.
- Ustun, T. S., Ozansoy, C., & Zayegh, A. (2011). Recent developments in microgrids and example cases around the world - A review. *Renewable and Sustainable Energy Reviews*, 15(8), 4030–4041. <https://doi.org/10.1016/j.rser.2011.07.033>
- Vaidya, A., & Mayer, A. L. (2016). Use of a participatory approach to develop a regional assessment tool for bioenergy production. *Biomass and Bioenergy*, 94, 1–11. <https://doi.org/10.1016/j.biombioe.2016.08.001>

- Valencia, F., Billi, M., & Urquiza, A. (2021). Overcoming energy poverty through micro-grids: An integrated framework for resilient, participatory sociotechnical transitions. *Energy Research and Social Science*, 75(August 2020), 102030. <https://doi.org/10.1016/j.erss.2021.102030>
- van de Grift, E., Cuppen, E., & Spruit, S. (2020). Co-creation, control or compliance? How Dutch community engagement professionals view their work. *Energy Research and Social Science*, 60(February 2019), 101323. <https://doi.org/10.1016/j.erss.2019.101323>
- van Summeren, L. F. M., Wieczorek, A. J., Bombaerts, G. J. T., & Verbong, G. P. J. (2020). Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands. *Energy Research and Social Science*, 63(May 2019), 101415. <https://doi.org/10.1016/j.erss.2019.101415>
- Vargas, C., Corrales, J., Angelov, P., & Iglesias, J. (2019). Methodology for Microgrid/Smart Farm Systems: Case of Study Applied to Indigenous Mapuche Communities. *Advances in Intelligent Systems and Computing*, 893. [https://doi.org/10.1007/978-3-030-04447-3\\_6](https://doi.org/10.1007/978-3-030-04447-3_6)
- Volken, S. P., Xexakis, G., & Trutnevyte, E. (2018). Perspectives of Informed Citizen Panel on Low-Carbon Electricity Portfolios in Switzerland and Longer-Term Evaluation of Informational Materials. *Environmental Science & Technology*, 52(20), 11478–11489. <https://doi.org/10.1021/acs.est.8b01265>
- von Wirth, T., Gislason, L., & Seidl, R. (2018). Distributed energy systems on a neighborhood scale: Reviewing drivers of and barriers to social acceptance. *Renewable and Sustainable Energy Reviews*, 82(September 2017), 2618–2628. <https://doi.org/10.1016/j.rser.2017.09.086>
- Waisman, H., Bataille, C., Winkler, H., & et al. (2019). A pathway design framework for national low greenhouse gas emission development strategies. *Nat. Clim. Chang*, 9, 261–268. <https://doi.org/10.1038/s41558-019-0442-8>

- Walker G, & Cass N. (2007). Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. *Area*, 39, 458–469.
- Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663. <https://doi.org/10.1016/j.enpol.2009.05.055>
- Walker, G., & Simcock, N. (2012). Community energy systems. In *International Encyclopedia of Housing and Home* (Vol. 1). Elsevier Ltd. <https://doi.org/10.1016/B978-0-08-047163-1.00598-1>
- Wang, Y., Rousis, A. O., & Strbac, G. (2020). On microgrids and resilience: A comprehensive review on modeling and operational strategies. *Renewable and Sustainable Energy Reviews*, 134(September), 110313. <https://doi.org/10.1016/j.rser.2020.110313>
- Warbroek, B., & Hoppe, T. (2017). Modes of governing and policy of local and regional governments supporting local low-carbon energy initiatives; exploring the cases of the dutch regions of Overijssel and Fryslân. *Sustainability (Switzerland)*, 9(1), 1–36. <https://doi.org/10.3390/su9010075>
- Ward, M., Schulz, A. J., Israel, B. A., Rice, K., Martenies, S. E., & Markarian, E. (2018). A conceptual framework for evaluating health equity promotion within community-based participatory research partnerships. *Evaluation and Program Planning*, 70(March), 25–34. <https://doi.org/10.1016/j.evalprogplan.2018.04.014>
- Warneryd, M., Håkansson, M., & Karltorp, K. (2020). Unpacking the complexity of community microgrids: A review of institutions' roles for development of microgrids. *Renewable and Sustainable Energy Reviews*, 121(December 2019). <https://doi.org/10.1016/j.rser.2019.109690>

- Warneryd, M., & Karltorp, K. (2022). Microgrid communities: disclosing the path to future system-active communities. *Sustainable Futures*, 4(January), 100079. <https://doi.org/10.1016/j.sftr.2022.100079>
- Warren CR, & McFadyen M. (2010). Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland. *Land Use Policy*, 27, 204–213.
- Wirth, S. (2014). Communities matter: Institutional preconditions for community renewable energy. *Energy Policy*, 70, 236–246. <https://doi.org/10.1016/j.enpol.2014.03.021>
- Wright, S., Frost, M., Wong, A., & Parton, K. (2024). Australian microgrids: Navigating complexity in the regional energy transition. *Energy Research and Social Science*, 113. <https://doi.org/10.1016/j.erss.2024.103540>
- Wu, L., Ortmeyer, T., & Li, J. (2016). The community microgrid distribution system of the future. *Electricity Journal*, 29(10), 16–21. <https://doi.org/10.1016/j.tej.2016.11.008>
- Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683–2691. <https://doi.org/10.1016/j.enpol.2006.12.001>
- Y. Wu, Y. Wu, J. M. Guerrero, J. C. Vasquez, & J. Li. (2019). AC Microgrid Small-Signal Modeling: Hierarchical Control Structure Challenges and Solutions. *IEEE Electrification Magazine*, 7(4), 81–88. <https://doi.org/10.1109/MELE.2019.2943980>.
- Yamashita, D. Y., Vechiu, I., & Gaubert, J. P. (2020). A review of hierarchical control for building microgrids. *Renewable and Sustainable Energy Reviews*, 118(November 2019), 109523. <https://doi.org/10.1016/j.rser.2019.109523>
- Yu, J., Marnay, C., Jin, M., Yao, C., Liu, X., & Feng, W. (2018). Review of Microgrid Development in the United States and China and Lessons Learned for China. *Energy Procedia*, 145, 217–222. <https://doi.org/10.1016/j.egypro.2018.04.038>

Zachar, M., & Daoutidis, P. (2015). Understanding and predicting the impact of location and load on microgrid design. *Energy*, 90, 1005–1023.  
<https://doi.org/10.1016/j.energy.2015.08.010>

Zhou, Y., Panteli, M., Moreno, R., & Mancarella, P. (2018). System-level assessment of reliability and resilience provision from microgrids. *Applied Energy*, 230(April), 374–392.  
<https://doi.org/10.1016/j.apenergy.2018.08.054>

# Chapter 6

Technology, People, and Place in  
Microgrids: Addressing  
Perceptions and Engagement  
challenges for a rural Australian  
town.

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## Chapter 6. Technology, People, and Place in Microgrids: Addressing Perceptions and Engagement Challenges for a rural Australian town.

### 6.1 Introduction to the chapter

This chapter presents the article under review titled "Technology, People, and Place in Microgrids: Addressing Perceptions and Engagement Challenges for a rural Australian town," which has been submitted in *Energy Research & Social Science*. The chapter responds to the last research question: "Are community engagement strategies in microgrids supporting social cohesion and public acceptance, or creating conflicts in the local community?" (see section 1.6). By examining a microgrid feasibility study conducted in Victoria, Australia, this research explores how community engagement strategies shape public perceptions, foster collaboration, or contribute to opposition and division. Using a mixed-methods approach, the study analyses community perspectives through in-depth interviews (n = 13) and survey responses (n = 62), highlighting the impact of place-based factors, community dynamics, and tailored engagement strategies. This chapter contributes to the growing discourse on the social dimensions of microgrids and help understand the impacts of community engagement activities on the social acceptance of microgrids.

## Abstract

Microgrids are emerging as a promising technological solution for providing reliable, sustainable, and cost-effective electricity to regional and remote communities. However, successful microgrid implementation necessitates not only technical and economic feasibility but also social acceptance within the communities where they are deployed. This paper presents a case study of a microgrid feasibility project in Victoria, Australia, employing a mixed-methods design to analyse community perceptions of microgrids and the role of engagement strategies in promoting community acceptance or leading to conflicts. Drawing on empirical findings from in-depth interviews (n = 13) and a community survey (n = 62), this research investigates the challenges and lessons associated with engaging a local community when investigating the feasibility of a proposed microgrid. The findings highlight the significant influence of place-based factors and community dynamics on project perception and social acceptance, emphasising the need for tailored engagement strategies that foster collaboration and maximise community participation. While best practices of community engagement do not guarantee community acceptance, this research demonstrates that proactive engagement and transparent communication can effectively address concerns and cultivate support for microgrid initiatives.

## 1. Introduction

The energy transition represents a complex and multifaceted process characterised by a shift away from carbon-intensive, centralised energy systems towards decentralised and decarbonised alternatives (Miller et al., 2013; Radtke & Scherhauser, 2022). Renewable energy sources are poised to play a pivotal role in Australia's clean energy transition. In 2024, renewable energy accounted for 40% of Australia's total electricity generation, up from 35.9% in 2022. Among the various sources, wind energy contributed the largest share, providing 13.4% of the nation's electricity, followed closely by rooftop solar, which supplied 12.4% of total generation (Clean Energy Council, 2025). Rooftop solar, which is predominantly located in urban and suburban areas, was the largest contributor in terms of capacity growth, with 3.2 GW added in 2024. While small-scale rooftop solar continues to rise rapidly in urban settings, utility-scale renewable energy projects, such as large solar farms and wind farms, are primarily located in rural and regional areas, where land availability and resource potential are more favourable (AEMO, 2023).

As the energy transition has gathered pace, local opposition to energy infrastructure siting has increased (Cuppen, 2018; Ocelík et al., 2021; Toke, 2005). This resistance has been conceptualised through various lenses, including perceptions of fairness (distributive and procedural justice), place attachment and identity (Koirala et al., 2016), populist and political ideology (Schubert et al., 2015), and community acceptance (de Abreu D'Aquino et al., 2024; Wolsink, 2012; Wüstenhagen et al., 2007). While the NIMBY (Not In My Backyard) concept has been widely debated, local conflicts and trade-offs are increasingly recognised as inherent aspects of the energy transition (Galjak & Budić, 2024; Hu & Han, 2023). Consequently, the role of local communities as key actors in shaping a sustainable energy transition has garnered significant attention in academic

literature (Farla et al., 2012; Giacobelli, 2022; Svobodova et al., 2020; Ullman & Kittner, 2024).

Participation and community engagement are considered potential solutions to avoid social conflicts and resistance to the projects (Franziska Mey Anne Kallies & Watson, 2023; Wolsink, 2018). Innovative community engagement strategies can promote collaboration between project teams and local stakeholders, leading to a reduction in social conflicts and an increased likelihood of social acceptance (Lomax et al., 2023; Radtke & Scherhauser, 2022; Sovacool et al., 2022). Empirical studies demonstrate that projects characterised by high levels of community engagement, consultation with local stakeholders, and participatory planning are significantly more likely to gain social acceptance compared to those with limited or minimal community involvement (Firestone et al., 2018; Komendantova et al., 2018; Osborne et al., 2021).

While participation and engagement possess a strong normative connotation and are widely regarded as important elements of community acceptance (Wüstenhagen et al., 2007), critics argue that these processes are resource-intensive, requiring substantial time and financial investments that may outweigh their benefits (Boudet, 2019; Jami & Walsh, 2017; Suboticki et al., 2023). This study aims to address these diverging perspectives and contribute to a more nuanced understanding of the opportunities and challenges associated with community engagement and participation in the context of microgrid development in rural Australia.

Renewable energy microgrids are gaining prominence as a transformative energy technology due to their capacity to enhance the reliability and resilience of the electricity supply in rural and remote communities (Jiménez-Estévez et al., 2017; Kirubi et al., 2009; Wu & Sansavini, 2020; Zhou et al., 2018). Microgrids are commonly defined as "a group of interconnected loads and Distributed Energy Resources (DERs) within a defined electrical boundary, operating as a single controllable entity with the capability of connecting or disconnecting from the main grid to operate independently in islanded

mode" (Olivares et al., 2014; Perez-DeLaMora et al., 2021; Tahir et al., 2024b). When integrated with renewable energy sources and battery storage systems, microgrids are increasingly recognised as a viable solution for providing resilient, reliable, and affordable electricity to rural and remote communities (Planas et al., 2015; R. H. Lasseter, 2002; Soshinskaya et al., 2014). In Australia, microgrids remain a niche, with the majority of pilot projects and feasibility studies conducted in Indigenous, rural, and remote communities, where they are explored as a solution to enhance energy autonomy, resiliency, and reliability in these communities (Department of Climate Change, Energy, the Environment, 2022; Tahir et al., 2024b; Wright et al., 2024). Although the technical aspects of microgrids have been explored extensively in the literature (Guerrero M. Josep & Kandari Ritu, 2021; Hirsch et al., 2018; Martin-Martínez et al., 2016), the social aspects, which are critical in the implementation of microgrids, have not been explored in detail (Chalaye et al., 2023; Eklund et al., 2023; Tahir et al., 2024a; Wright et al., 2024).

Guided by an action research approach, this study investigated the following overarching research question: What are the challenges and drawbacks associated with engaging a local community in the conceptualisation and feasibility stages of a microgrid solution? Specifically, this research examines how community engagement strategies influence perceptions of the project and whether these strategies foster social acceptance or give rise to conflict. Furthermore, this study explores the potential misconceptions surrounding the notion of "good practice" in community engagement, highlighting the limitations of standardised approaches that may not adequately address the complexities and unique dynamics inherent in specific communities. By analysing these challenges and complexities, this research aims to generate valuable insights and lessons learned to improve the design and effectiveness of community engagement processes in microgrid development.

## 2. Literature review: Social acceptance and exploring community engagement in the microgrid projects

The successful deployment of microgrids, like any technological solution, necessitates consideration of not only technical and economic factors but also crucial social dimensions (Creamer et al., 2019; Murunga et al., 2024). As renewable energy projects, including microgrids, are increasingly deployed in and around rural communities, the question of their social acceptance by these communities becomes paramount. Wüstenhagen et al. (2007) define social acceptance in the context of renewable energy projects as "the acceptance of siting decisions and related policies by local stakeholders, particularly residents and local authorities (Wüstenhagen et al., 2007)." This acceptance is critical for the progress and success of renewable energy projects, including microgrids (Scovell et al., 2024). Conversely, a lack of community acceptance and the presence of local opposition can significantly hinder the implementation of such projects (Ansolabehere & Konisky, 2014).

The academic literature demonstrates that local communities have exhibited resistance to various renewable energy technologies, including wind energy, primarily due to visual and noise impacts (Colvin et al., 2016; Dunning & Turner, 2005; LaPatin et al., 2023), geothermal energy over the risk of groundwater contamination (Dowd et al., 2011), smart meters for privacy concerns (Sovacool et al., 2022), large-scale solar farms, owing to land conflicts (Scovell et al., 2024), tidal energy due to ecological impacts (Patrick Devine-Wright, 2011), and nuclear energy for safety concerns (Baron & Herzog, 2020). Consequently, community acceptance is critical for the successful deployment of renewable energy technologies, as it can significantly influence project implementation and long-term sustainability (Geels et al., 2017; Sovacool et al., 2017; Upham et al., 2022).

Effective community engagement is widely recognised as a critical component in achieving social acceptance of renewable energy projects, and it can play a pivotal role in the successful implementation of low-carbon distributed technologies, such as microgrids (Koirala et al., 2018; Waisman, H., Bataille, C., Winkler & et al., 2019; Walker G & Cass N, 2007; Warren CR & McFadyen M, 2010). Engaging with local communities leads to the development of trust and partnership between community members and project stakeholders, which is integral for successful project implementation (Gordon et al., 2013; Irvin & Stansbury, 2004; Vargas et al., 2019; Walker et al., 2010; Warbroek & Hoppe, 2017). Besides, respecting local stakeholders involved in the engagement process and considering their input in decision-making is significant for developing a sense of ownership and legitimacy in the project (Fombrun et al., 2018; Marinakis et al., 2017; McGookin et al., 2021; Vaidya & Mayer, 2016). Projects with active public participation and meaningful stakeholder input are more likely to be accepted by the local community, resulting in reduced social conflicts and opposition (Fragniere et al., 2023; Međugorac & Schuitema, 2023). Various community engagement strategies can be employed to enhance community acceptance, with their application depending on the specific project requirements and scope (Chapman & Pambudi, 2018; Flood et al., 2018; Volken et al., 2018). Diverse community engagement methodologies, such as community surveys, questionnaires, interviews, webinars, workshops, community fairs, town hall events, scenario generation, and serious game approaches, are widely used in renewable energy projects (Ernst et al., 2018; Kowalski et al., 2009; Li & Pye, 2018; Tahir et al., 2024a).

While evidence suggests that effective community engagement can lead to increased acceptance of renewable energy projects and facilitate the achievement of decarbonisation targets, integrating public perspectives into decision-making processes presents inherent complexities and challenges as well (Jami & Walsh, 2017). Community engagement can be resource-intensive, and poorly planned strategies may lead to conflict and opposition within communities (Oteman et al., 2014; Rowe & Frewer, 2000).

For instance, excessive information disclosure during webinars and workshops can result in information overload and misconceptions among participants (Fischer, 2009). Additionally, community groups with limited technical knowledge may encounter difficulties in comprehending complex project details, potentially hindering consensus-building and exacerbating conflict (McCallum & Santos, 1997). These challenges highlight the complexities associated with integrating public input into decision-making processes, particularly for projects involving technically intricate or contentious issues.

Despite the growing interest in microgrids as a decentralised energy solution, limited research has been undertaken in understanding the social acceptance of microgrids (Tahir et al., 2024a), creating a significant gap in the existing literature. For instance, Chalaye et al. (2023) developed a place-based methodology for site selection, focusing on socio-technical considerations (Chalaye et al., 2023). Eklund et al. (2023) conceptualised the representation of community preferences across project stages, proposing a social capital-based framework to identify community characteristics (Eklund et al., 2023), while Eklund et al. (2024) applied a Multi-Criteria Decision Analysis framework to evaluate microgrid business models (Eklund et al., 2024). Farrelly and Tawfik (2020) examined four Victorian microgrid projects, identifying common drivers and challenges (Farrelly & Tawfik, 2020). Wright et al. (2024) applied a Strategic Niche Management lens to assess microgrids as niche innovations, focusing on stakeholder engagement, ownership, and business models, and highlighting key barriers (Wright et al., 2024). Tahir et al. (2024a) presented empirical findings on the drivers and barriers within a microgrid feasibility study, offering policy recommendations to inform future funding programs and regulatory frameworks (Tahir et al., 2024b). Additionally, Tahir et al. (2024b) conducted a qualitative analysis of community engagement across regional and remote microgrid feasibility studies, identifying challenges and strategies for more effective engagement (Tahir et al., 2024a). Besides this research on the social aspects of microgrids (Hirsch et al., 2018; Martin-Martínez et al., 2016; Warneryd et al., 2020),

the literature on the factors influencing social acceptance around microgrids still remains underexplored. Furthermore, the complex role of community engagement in microgrid projects requires further investigation, as engagement outcomes can vary significantly, ranging from promoting acceptance to creating opposition and conflict (Tahir et al., 2024a).

Examining a case study from a rural Australian community provides a valuable opportunity to assess the effectiveness of community engagement strategies in enhancing social acceptance of microgrid projects. Analysing a specific case study will reveal whether employed community engagement strategies are achieving their intended objectives and, if not, identify key insights and lessons learned to refine future approaches.

### 3. Theoretical framework: Technology, People, Place, and Process

To explore community perceptions of microgrids and engagement strategies in regional areas, multiple theoretical frameworks were reviewed. The Theory of Planned Behaviour (Wolske et al., 2017) was considered but found insufficient for capturing community-level dynamics. The Diffusion of Innovation framework (EM Rogers et al., 2014; Schelly, 2014) offered insights into how new ideas spread within communities, while Social Practice Theory, and Arnstein's Ladder of Participation provided complementary perspectives (Arnstein, 1969). However, none fully addressed the contextual and collective aspects of engagement central to this study's aims. This research primarily employs Hilary Boudet's "Technology, People, Place, and Process" framework to understand the role of community engagement in shaping social acceptance of microgrids (Boudet, 2019). This framework offers a comprehensive approach to analysing the complex interplay between technological developments and their social contexts, recognising the influence of various factors on community perceptions and project outcomes. The framework also provides a systematic approach to understanding how infrastructure or technological

developments interact with social contexts, identifying technology, people, place and process as factors influencing a community's perception towards renewable energy technology (Boudet, 2019). This framework serves as a guiding structure for this research, with each element elaborated upon below.

### **Technology**

The analysis of the potential benefits and associated risks of certain technology will often determine the perception of that technology within a local community (Boudet, 2019). For instance, public perception studies have found that fossil fuel generation is considered more risky and less appealing as compared to renewable energy technologies (Bergquist et al., 2020). In this research, the perception around microgrids was analysed in the context of a feasibility study conducted by a team of researchers, practitioners and local community leaders.

### **People**

This dimension of the framework highlights the influence of different sociodemographic factors on an individual's attitudes and behaviours toward the adoption of new technologies. For instance, some have found that women and young adults with higher education and higher income are generally more supportive of renewable energy projects compared with older generations, who can be more reluctant to change (Schelly, 2014). The case study captured the profile of the community group and investigated its different views and opinions surrounding microgrids.

### **Place**

This dimension of the framework encompasses the influence of landscape, physical infrastructure, demography, layout, network topology, and historical experiences on community perceptions of new technologies (Osborne et al., 2021). These place-based factors can significantly influence the suitability and feasibility of different energy technologies within a given locality. For instance, proximity to cost-effective renewable

energy resources (e.g., wind, hydro, biomass) and the existing configuration of the electricity distribution network will profoundly shape the technological choices available for community energy projects.

## Process

Process-based strategies are critical in shaping community perceptions and acceptance of new technologies (Agterbosch et al., 2009; Tricarico, 2021). In the context of energy projects, the nature and extent of community engagement, including how communities are involved in decision-making processes, significantly influence their perceptions and acceptance of the project. Effective community engagement strategies aim to foster trust, transparency, and open communication, ensuring the community's right to participate and contribute to decision-making.

The research will be underpinned by this theoretical framework, providing a structural lens to examine the role of technology, people, place and process in social acceptance of new technology. Figure 34 provides a summary of the different dimensions of the framework.

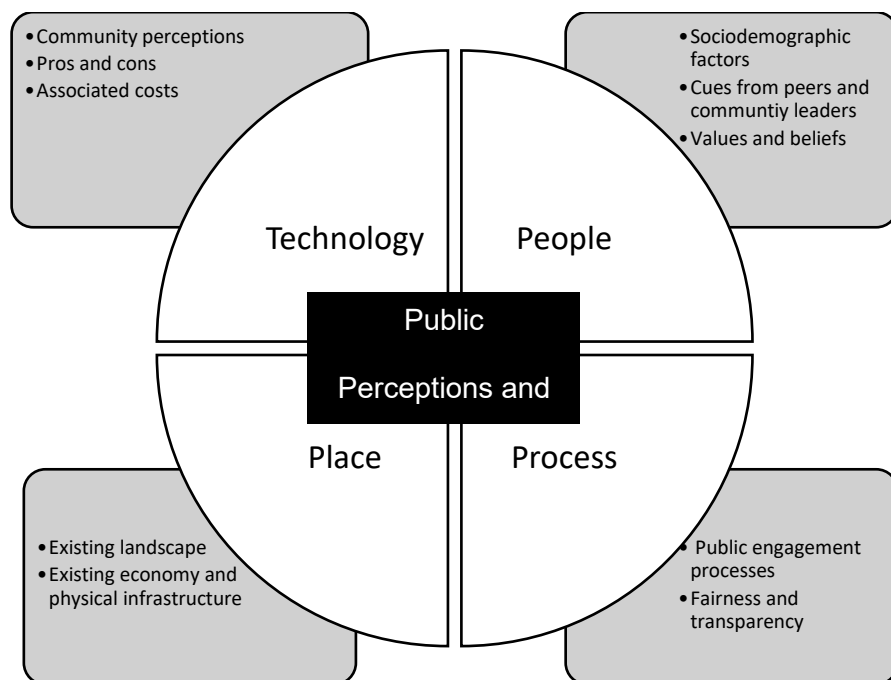


Figure 34 Technology, People, Place and Process Framework for understanding public perceptions and responses. Retrieved from Boudet's framework (Boudet, 2019)

## 4. Methodology

A mixed-method case study methodology was employed to facilitate an in-depth exploration of the factors contributing to the social acceptance of complex community energy projects, such as microgrids. A case study is defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, utilising multiple sources of evidence (Yin, 2009). This approach enables a comprehensive understanding of community experiences and the multidimensional nature of community engagement within rural contexts, capturing complexities that might be overlooked in broader qualitative studies. Furthermore, the case study approach allows for the integration of theoretical concepts with empirical observations, potentially leading to the generation of new hypotheses and theoretical insights (Yin, 2009).

A case study from a rural Australian town is particularly relevant as they were identified by the Australian government as a key focus for microgrid feasibility funding, due to their geographical location, less reliable and resilient energy supply, and higher energy costs. Lessons learned from this case provide valuable insights that can inform and guide similar initiatives in other communities across Australia (Tahir et al., 2024b).

The ethics application for this research (approval number: ETH22-7296) was prepared and submitted by the lead researcher and subsequently approved by the university's Human Research Ethics Committee. The project was classified as low risk. The application detailed the research methodology, participant recruitment processes, funding sources and disclosure of interests, as well as protocols for data collection, use, and participant involvement. Approval was granted to conduct both qualitative and quantitative components of the study. Prior to participation, interviewees were provided with a Participant Information Sheet outlining the purpose of the research, the reasons for their selection, potential risks, and how their data would be used. Contact information was also provided to address any questions or concerns participants may have had.

## 4.1 The case of Heyfield

As host of the MyTown Microgrid project, Heyfield, an Australian rural town in Victoria's Gippsland region with a population of approximately 2,000 residents, was selected as the primary case study for this research. Initiated in 2020 with federal and state government funding, the MyTown project aimed to assess microgrid feasibility and engage the community in the planning process. The Heyfield MyTown Microgrid project aimed to undertake a detailed data-led microgrid and local energy feasibility study for the town of Heyfield (Victoria), built on a platform of deep community engagement and capacity building. At the core of this project was a novel community engagement approach which sought to empower the local community to own and progress the idea of a local microgrid supported by a team of researchers from different disciplines. Over the three-year duration, the project also aimed to develop the knowledge and tools to make it faster, easier, and cheaper for other regional communities to understand local energy propositions for their community. The project's ultimate goal was to serve as a blueprint for a community-led approach towards understanding the feasibility of a local microgrid solution.

The project team, comprising members from the community, industry, academia, and government, sought to examine the microgrid value proposition for Heyfield while fostering community capacity and knowledge regarding clean energy solutions.

Sociodemographic factors, cultural norms, peer influence, and trust can all shape individual and collective perceptions of new technologies (Boudet, 2019). While sociodemographic factors such as age, gender, and religious affiliation can play a significant role in shaping perceptions, the analysis of the Heyfield case study did not reveal these factors to be critical in shaping perceptions of microgrids.

According to the Australian Bureau of Statistics (ABS) census data, the population of Heyfield is relatively evenly distributed between males (51%) and females (49%), with

an average age of 47 years (Australian Bureau of Statistics, 2023). Furthermore, the region exhibits limited ethnic diversity. As illustrated in Table 15, the highest population density is found in the 55-75 age group, significantly higher than the national average. This suggests that many Heyfield residents are retirees or older individuals.

*Table 15 Heyfield Demographics: Average age Vs age in Australia*

<b>Age group</b>	<b>Occurrence in Heyfield</b>	<b>Percentage in Heyfield</b>	<b>Percentage in Australia</b>
0-4	78	3.8	5.8
5-9	108	5.2	6.2
10-14	138	6.7	6.2
15-19	153	7.4	5.7
20-24	71	3.4	6.2
25-29	120	5.8	7.0
30-34	90	4.4	7.3
35-39	104	5.0	7.2
40-44	95	4.6	6.5
45-49	128	6.2	6.4
50-54	116	5.6	6.3
55-59	167	8.1	6.1
60-64	122	5.9	5.8
65-69	162	7.8	5.1
70-74	171	8.3	4.6
75-79	105	5.1	3.2
80-84	69	3.3	2.2
85 and older	68	3.3	2.1

The median age in Heyfield is 47, notably higher than the national median of 38, indicating an older population profile in the region.

Figure 35 presents the demographic profile of Heyfield, detailing language spoken, population distribution by gender, country of birth, and Indigenous identification. Similarly, Figure 36 illustrates that 46% of Heyfield's population is currently employed, while 43% are retired or otherwise out of the workforce. This demographic composition contrasts with the employment data for Victoria and Australia overall, where a higher proportion of

individuals are employed. The data suggests that Heyfield's population is characterised by a predominance of retirees and an older demographic profile.

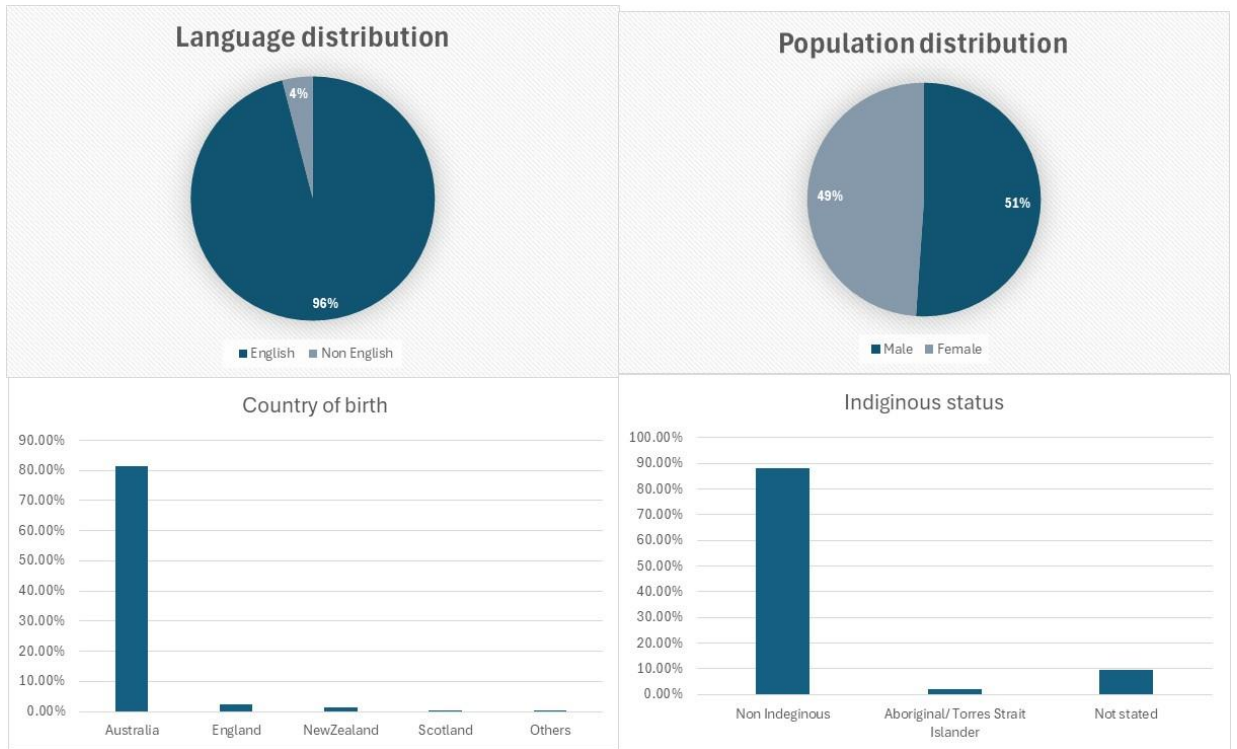


Figure 35 Heyfield Demographics

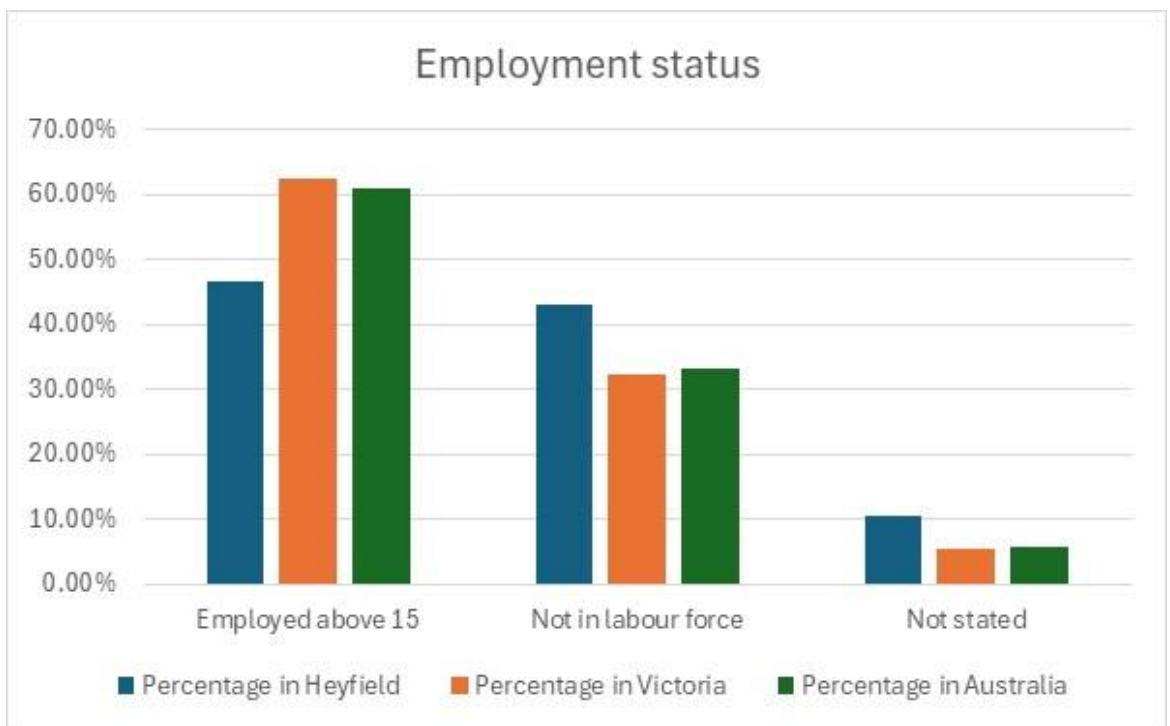


Figure 36 Heyfield employment data

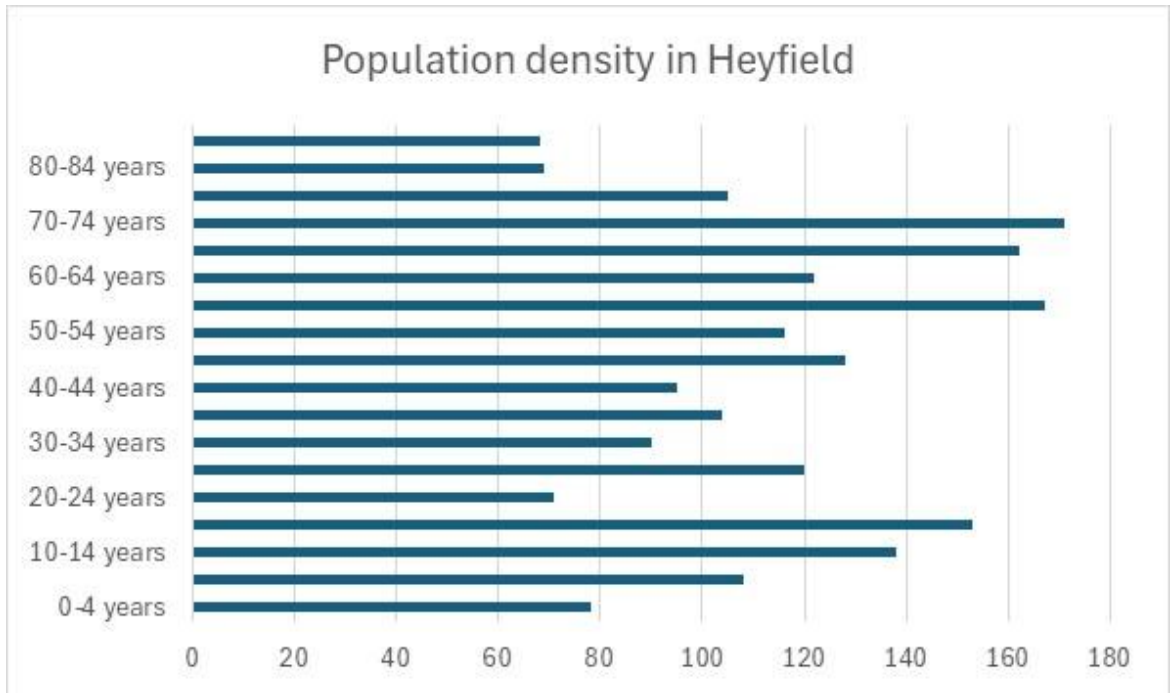


Figure 37 Heyfield Population Density

Established in 1841 due to its proximity to abundant timber resources, Heyfield's early economic development was inextricably linked to the timber industry. In subsequent decades, its location near the Latrobe Valley led to its emergence as a source of labour for the region's three coal-fired power plants, attracting workers from other areas. However, both the timber and coal industries are currently undergoing fundamental transitions to meet the challenges of more sustainable practices. Consequently, Heyfield has evolved beyond its historical industrial identity, seeking new pathways towards economic and environmental sustainability.

To facilitate effective communication and collaboration between the project team and the community, a dedicated Community Liaison Officer (CLO) position was created. The CLO served as a central point of contact, responsible for coordinating communication and engagement activities between the project team and the Community Reference Group (CRG). Figure 38 provides a visual representation of the key tasks and

responsibilities associated with the CLO role.

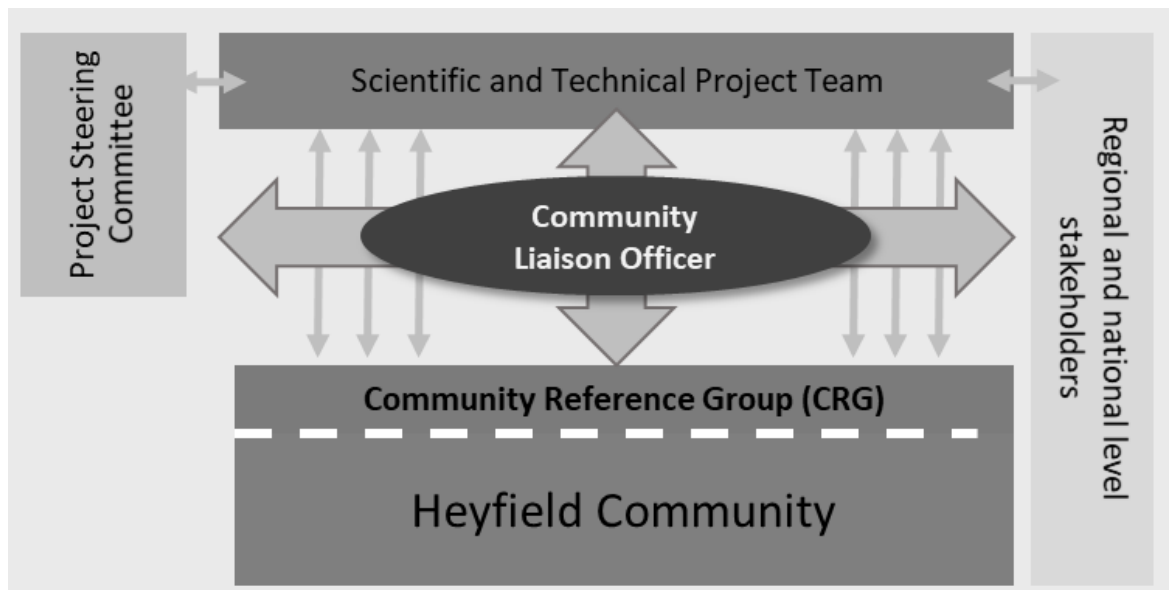


Figure 38 Role of CLO and CRG (adopted from the Heyfield conceptual data and analytical report (Langham et al., 2021))

In addition to the Community Liaison Officer, a Community Reference Group (CRG) was established to represent the broader community and provide input into the project's decision-making processes. The CRG served as a direct conduit between the project team and the local community, ensuring community perspectives were incorporated into project development. The group met regularly at the Heyfield Community Resource Centre (HCRC) to discuss project progress, research findings, and community feedback. The CRG's input significantly shaped the project's direction and outcomes.

The techno-economic analysis of a potential islandable microgrid solution for Heyfield revealed a marginally beneficial option for the community for just one of the scenarios investigated. Ultimately, the community and project team decided that the economic benefit was, therefore, not strong enough to warrant progressing with the implementation of the microgrid, given the major risks involved. However, alternative aspects of the microgrid that were evaluated (specifically various types of battery energy storage systems) did prove more feasible on their own and were the subject of a separate feasibility study, which was granted state funding to pursue (The details of the

alternatives pursued have been stated in the appendix as an alternative to the microgrids). While some community members expressed disappointment, as they had invested time in understanding the microgrid value proposition, the project team emphasised the need to prioritise the provision of optimal energy solutions for the community by exploring alternative technologies.

## 4.2 Mixed Methods approach

To explore the role of community engagement in shaping the social acceptance of microgrids under the lens of the Technology, People, Place and Process framework, this research employed a mixed-method approach for the data collection. To gather diverse perspectives from key stakeholders involved in the MyTown microgrid project, this research utilised a mixed-methods approach incorporating semi-structured interviews, community surveys, and document analysis. To ensure ethical integrity and transparency, this paper was led by a PhD candidate with a university scholarship, who conducted all the interviews and surveys. The other co-authors were drawn from the project team that were able to provide the necessary project context, while also contributing to the conceptual development, supervisory support, formal analysis, and reviews. The research process and interpretation of findings were led by the PhD candidate, but still as a collaborative effort, with a high degree of attention paid to maintaining the independence and integrity of the research through the ethical procedures that were followed.

### **Semi-structured interviews with the Community Reference Group**

Semi-structured interviews (n=10) were conducted with members of the Community Reference Group (CRG), who were actively involved in the project's decision-making processes and contributed community perspectives throughout the project. Members of the Community Reference Group (CRG) were recruited voluntarily, following an advertisement for the role in the local community newsletter. Interested individuals

contacted the project team to express their willingness to join. Given their active involvement and ongoing engagement with the project, all the CRG members (n=10) were selected as interviewees for this study. Interview questions explored participants' roles in the project, the extent of community inclusion in decision-making, challenges encountered during the engagement process, initial perceptions of the project, and overall perspectives on project outcomes. The semi-structured format, with interviews lasting approximately 20-30 minutes each, enabled flexibility in exploring the process-related dimensions of the "Technology, People, Place, and Process" framework.

### **Semi-structured interviews with the project team**

Additionally, semi-structured interviews (n = 3) were conducted with project team members directly involved in the design and implementation of community engagement strategies. The project team interviewees were selected based on their roles and active involvement across key components of the project. Three team members were interviewed, each contributing to distinct aspects of the initiative, including community engagement, project management, and techno-economic analysis. Their selection aimed to ensure representation of diverse perspectives within the project team and to capture insights from those directly involved in the design and implementation processes. These interviews explored the development, implementation, and perceived effectiveness of the strategies employed.

### **Survey of local perspectives regarding microgrids**

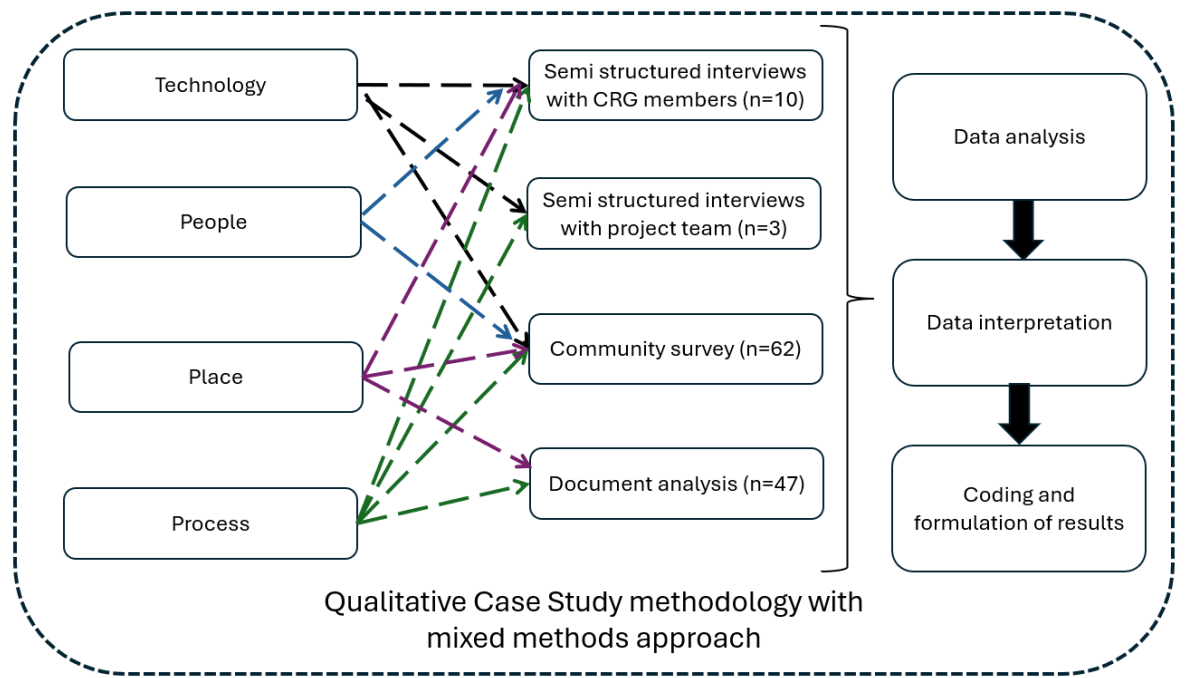
To explore broader perspectives beyond those of the CRG, a survey (n=62) was conducted with members of the Heyfield community to understand general attitudes and perceptions related to the project. The survey aimed to assess the community's general understanding of microgrids, their familiarity with the outcomes of the MyTown project, and their perceptions of renewable energy microgrids, with the broader objective of capturing perspectives beyond those directly involved in the project. The survey

incorporated both closed- and open-ended questions, exploring community perspectives on an ideal power system for the town, familiarity with renewable energy technologies, and willingness to adopt new technologies such as microgrids. The survey was distributed using both online and in-person methods. For the online distribution, the survey link was shared via email with individuals subscribed to the local community newsletter. In-person distribution was conducted through direct engagement with residents on the streets, in front of the market, as well as at key community locations such as the local resource centre and during town hall events. These multiple distribution channels were used to reach a broader cross-section of the community and to include those who may not engage regularly with digital platforms. The survey was open to all Heyfield residents, with participants recruited both randomly on the street and through online distribution channels.

### **Document analysis**

Additionally, document analysis (n = 47) was conducted to complement the primary data collection. These documents included MyTown microgrid project reports, workshop outputs, presentation materials, prior project documentation, and other resources on the Heyfield MyTown Microgrid Project. The documents were reviewed to provide contextual depth, triangulate findings from the interviews and surveys, and situate the research within the broader socio-technical landscape of microgrid development in Australia.

By integrating qualitative case study methodology with mixed methods for data collection, this research methodology leverages the strengths of the "Technology, People, Place, and Process" framework to comprehensively address the research objectives. Figure 39 provides a visual representation of how the mixed-methods approach aligns with the four dimensions of the framework, illustrating the interconnectedness of the various data collection methods and analytical lenses.



*Figure 39 Mixed-method approach*

### 4.3 Data interpretation analysis

Interviews were audio-recorded with the participant's consent and later transcribed for analysis. Field notes were also taken to capture non-verbal cues and contextual information. Ethical protocols were followed throughout the interview process, including obtaining informed consent from participants, ensuring confidentiality, and addressing any potential biases.

The recorded data was transcribed, and transcripts were reviewed for any errors. After the review, NVIVO 12 was used to code the data to identify recurring themes and insights related to the Technology, People, Place, and Process framework. A thematic analysis approach was employed to identify key patterns and themes emerging from the interview data, and themes were analysed using the technology, people, place, and process framework.

Transcribed interview data (including data from both CRG members and project team) were imported into NVivo 12 for qualitative analysis. A thematic analysis approach was employed using a deductive coding framework based on the Technology, People, Place,

and Process (TPPP) model. Initial parent nodes were created corresponding to each of the four elements of the TPPP framework. Within each node, sub-nodes were inductively generated to capture recurring themes and emerging insights from the data. Field notes were also coded in NVivo to supplement and contextualise interview findings. Coding was done iteratively, with regular checks for consistency and accuracy.

#### 4.4 Mitigating Potential Bias

While qualitative interviews provided valuable insights into the research, there are potential biases that must be acknowledged. Some members of the author team were also part of the broader project team involved in the Heyfield MyTown Microgrid Project. These members were included in the interview process as well to get the project team's perspective. However, to address the potential bias, the lead author, who is a PhD candidate and had no formal role in the community engagement component of the project, conducted all qualitative data analysis independently. Interview data were de-identified before analysis, and transcripts involving authors as participants were coded alongside others but checked against non-author interviews for triangulation. Coding decisions were reviewed by another independent researcher (stated as an author) not involved in the project. Other authors were involved in the review process and were not part of the analysis, thus reducing bias and maintaining research integrity.

The CRG members interviewed were self-selected volunteers who had actively approached the project team to participate. As such, they were likely more interested, engaged, and supportive of the project, potentially introducing a positive bias in their responses. Additionally, interviews were conducted with members of the project team who were directly involved in the development and implementation of the microgrid project. Although these interviews were carried out independently by the researcher, there remains the possibility of bias in favour of the project's outcomes and processes.

These potential biases are acknowledged in the analysis and have been considered when interpreting the findings.

## 5. Results- Through the lens of Technology, People, Place, and Process Framework

This section presents the findings from the qualitative case study, analysed and interpreted using the "Technology, People, Place, and Process" framework.

### 5.1 Technology

This section reveals the Heyfield community's perceptions around microgrids and how they view and perceive it. A post-project survey revealed a significant lack of prior awareness regarding microgrids, with only 28% of respondents indicating prior knowledge. This finding underscores the conceptual complexity of microgrid technology in terms of community comprehension.

The definitions communicated by the project team to the community were based on the technical and scientific perspectives, including the following:

*"Microgrids are defined as a group of homes and businesses that use, generate, and share electricity. It may be able to function both as part of the grid and autonomously. It will typically comprise solar PV systems or small wind farms to generate the majority of the electricity required, a battery system to store the electricity, a backup generator (typically diesel-powered), and power electronics to convert energy and manage the system"*

However, the community survey revealed that participants' initial expectations of microgrids varied from the proposed definition, ranging from grid-connected systems to community-based power sharing. Figure 40 presents a word cloud generated from the Heyfield survey responses, capturing the diverse range of community expectations

regarding microgrids. The heterogeneity of responses reveals the complexity and breadth of community understanding surrounding microgrids.



Figure 40 Word Cloud for Microgrids Community Perception gathered from the Heyfield survey

One interviewee from the CRG group expected the microgrid to be a tool for locally generated renewable energy. He stated:

*“I didn’t really know what a microgrid meant. And I thought a microgrid would be we’d buy all the power from Heyfield, and we’d sell it back to the community. That’s what I thought a microgrid was. Although I would love to see something like that happening”.*

**(Community Reference Group, Interviewee 3)**

This reflects the disconnect between the technical definitions of microgrids and community perceptions and expectations around them, underscoring the importance of clear communication and engagement to bridge this gap. The research also indicated that the majority of the community members were not aware of the term “microgrids”

before the MyTown project, requiring additional efforts from the project team in conveying the right messaging and raising awareness about microgrids.

## 5.2 People

This part of the results section, under the 'people' dimension of the framework, highlights how demographic factors influence perceptions of microgrids. The data from the CRG interviews revealed the significant influence of word-of-mouth communication and peer influence in shaping community perceptions of the microgrid project in the Heyfield community. Information and ideas disseminated organically through personal networks, with individuals sharing their experiences and perspectives with peers, played a crucial role in shaping community attitudes towards microgrids. This natural dissemination of information through word of mouth and peer influence, beyond formal engagement channels, was important in shaping the perception of the people in the community. The Community Reference Group (CRG) members, who participated voluntarily and played an integral role in the project, were largely influenced to become involved through peer encouragement and community networks. An interviewee who was an integral part of the CRG group commented regarding setting up the group:

*“And when we got this grant. And so I'd set up this core set up, if you want to say, cheekily set up this core of people who are new if we got anywhere with our funding, hoping that they would get involved. It's always been me talking about it...Because people know me so well. And I know, they know my beliefs.” (CRG Interviewee, 4)*

Another interviewee, when discussing the strong community-oriented nature of Heyfield, stated:

*“I think, I think it's Heyfield itself, which is a very community-oriented town. So it's quite unified with the idea of like, work from Heyfield would do stuff for Heyfield. So, you know, as a consequence, that makes it that's beneficial to starting any kind of project.” (CRG Interviewee, 6)*

Similarly, a project team member also seconded that result, stating that:

*“Heyfield is a proud, close-knit community with deep roots as a timber town. Over the years, they've shown a remarkable ability to adapt and evolve, embracing sustainability as a shared vision for the future. The town takes real pride in its local initiatives—from community-led projects to environmental innovation—and that strong sense of identity and collaboration made it an ideal place to trial a microgrid feasibility study.”*

**Project team interviewee 2**

Another theme that emerged from the interviews was a strong community interest in the ownership of energy assets. The survey included a specific question on community ownership of energy infrastructure, asking participants whether they would be interested in owning energy assets. Results indicated that 63% of respondents expressed interest in forms of ownership such as community-scale batteries, solar installations, and microgrids. This finding suggests that a substantial portion of the community recognises the potential benefits of local ownership, including greater energy autonomy, opportunities for revenue generation, and enhanced community participation in energy transition initiatives. However, participants also highlighted the need for greater support and clarity around potential business models and ownership structures to enable meaningful participation. For many, the concepts of joint ventures, cooperatives, or community trusts were unfamiliar or complex, raising concerns about financial risk, governance responsibilities, and legal requirements.

An analysis of the Heyfield community demographics, as outlined in Section 4.1, indicates a high proportion of retirees within the population. Our analysis has revealed that in such communities, traditional modes of engagement, particularly word-of-mouth communication and peer influence, are especially effective in shaping perceptions and fostering behavioural change. This observation is also consistent with findings in the wider literature, which highlight the importance of informal, trust-based communication

networks in influencing attitudes and behaviours in similar community contexts (Loomis & Tonnies, 2017; Tahir et al., 2024a; van Summeren et al., 2020).

While digital or technology-driven engagement strategies may prove effective in other contexts, in towns like Heyfield, securing the support of trusted local leaders is essential to ensure accurate information is disseminated throughout the community. In this context, trust emerges as a critical factor in community engagement.

Survey findings further reinforce the significance of community identity and values. When respondents were asked about their vision of an ideal power system, the majority described it as self-sufficient, community-owned, reliable, and beneficial for the local population. This strong sense of community cohesion was reflected throughout the survey responses.

Notably, 81% of participants indicated awareness of the MyTown Microgrid Project. Of these, 75% reported learning about it through the Heyfield Community Resource Centre, while 20% cited word-of-mouth as their primary source. These findings highlight the importance of leveraging existing community networks and relationships in the design of engagement strategies. Future energy projects would benefit from tailoring community engagement processes to local contexts, with careful consideration of demographic characteristics and social dynamics.

### 5.3 Place

This dimension of the framework states that historical characteristics of a place where the population is situated significantly shape its community's perception of new technologies and initiatives (Kim & Chung, 2019). In the case of Heyfield, the community has demonstrated a history of embracing sustainability initiatives, including those related to energy and water efficiency. This historical context suggests a potential receptiveness to innovative energy solutions, such as microgrids, which align with the community's established values and priorities.

Heyfield is an excellent example of how a community can transform its energy landscape, shifting from a primary industry-based, extractive past to one that seeks to embrace a more environmentally sustainable future. The town has a demonstrated high level of volunteerism and is familiar with the sustainability work being undertaken by the Heyfield Community Resource Centre, which is supported by the community. The Heyfield Community Resource Centre (HCRC) initiated and led the Sustainable Smart Town program in which almost half of Heyfield's households were engaged in a three-stage program. It involved a bulk purchase scheme for solar panels, flag installations for behaviour change, and posting coloured stickers on letterboxes to acknowledge participation in the program. The flag system was a crucial component to the program's adoption, demonstrating the locals' adoption of water, energy and waste efficiency measures: a white for taking the first steps in the program, a blue flag for making their home or business more sustainable, and a green flag recognises homes and businesses that have significantly reduced their carbon footprint. The great success of this initiative was recognised with the World Environment Day Award from the United Nations Association of Australia in 2011.

An interviewee who was actively involved in the project stated:

*"We worked with the community, you know, 13 years ago, on our flag programme with the locals that lived here through that. They were so supportive, because they knew what we achieved with our flag programme, you know, with the United Nations award. Yeah. We were finalists for the Premier's Award, and we won the Sustainability Award."* (CRG Interviewee, 7)

Heyfield has also won other accolades since embarking on the renewable energy journey, which are presented in Table 16.

*Table 16 Awards and accolades won by Heyfield as a community for its sustainable initiatives*

<b>Award won</b>	<b>Year</b>
Energy Globe Awards – National Winner (Australia)	2023
Climate Action Award Finalist –Neighbourhood Houses Victoria	2021
ACFE Learn Local Legend - Gippsland Region	2018
Australia's Strongest and Most Resilient Community	2017
Finalist Wellington Shire Council Community Group of the Year	2017
World Environment Day Awards	2011
Finalist State Premiers Award	2011
Prime Super winner	2011
Pam Keating Tidy Town winner	2011
Winners of United Nations of Australia Assoc "World Environment Day Awards" for the Heyfield Sustainable Smart Town Program	2011

Results from the survey indicated that 95% of respondents expressed support for initiatives related to the energy transition. This included a general willingness to embrace new technologies and a positive attitude toward participating in community energy projects such as microgrids. This finding aligns with the project team's observation that the community exhibited a progressive stance towards adopting innovative energy solutions.

## 5.4 Process

This section of the framework investigates the role of project processes in shaping the perceptions of the local community. The community engagement process aimed to enhance collaboration and knowledge sharing between the project team and selected

community members, facilitating a shared understanding of microgrid solutions and incorporating regular feedback. This approach sought to enhance community capacity building, ensure knowledge transfer, and promote the acceptability of microgrids.

The project team implemented various engagement initiatives to broaden community involvement and raise awareness about microgrids. These initiatives aimed to inform residents about the project and encourage their active participation. Table 17 provides a comprehensive overview of the community engagement strategies employed during the project. The data presented in this table were derived from the interviews conducted with the project team (n=3) and by analysing the project reports. The engagement activities were tailored to the local context, ranging from formal town hall meetings and CRG discussions to informal street-level interactions and educational outreach in schools. Collectively, these initiatives demonstrate the team's effort to build trust, enhance technical understanding, and ensure inclusive participation in the project.

Table 17 Overview of Community Engagement Strategies employed in Heyfield

<b>Community engagement strategy</b>	<b>Elaboration</b>	<b>Rationale</b>
<b>Town hall events</b>	Conducting town hall events to engage the community about the project, talking about the project scope and associated benefits	Creating awareness of the project and educating people about the potential benefits.
<b>On-street engagement</b>	Recruiting people to participate in the decision-making process and community reference groups.	Engaging more people to be a part of the project.
<b>Weekly meetings</b>	Fortnightly meetings with the CRG members to keep them updated about the project's progress, seeking their input on the matters	Capacity building and enhancing knowledge in the CRG members and community liaison officers.
<b>Webinars and workshops</b>	Conducting online or face-to-face webinars and workshops to enhance technical knowledge and create energy literacy in the community.	Capacity building and enhancing technical knowledge in the CRG members and community liaison officers
<b>On School engagement</b>	Engaging with school children to create energy literacy at the school level, targeting the future generation.	Intergenerational engagement
<b>Poster presentation</b>	Poster presentations in the HCRC highlighting the important information about the project	Creating awareness of project deliverables and outcomes to the local community members
<b>Community Dashboard</b>	Communicate information on the project to the wider Heyfield community at highly visible sites accessible to the public.	Demonstrating project outcomes, increasing awareness and energy literacy in the local community
<b>Project video demonstration</b>	A 10-minute video documentary was made to educate the community about the project's journey and outcomes.	Disseminating the research findings
<b>Media reports and coverage (newsletter)</b>	A monthly newsletter to keep the community aware of the project progress and outcomes	Creating awareness in the local community
<b>Community fairs</b>	Preparing a stall in a local community fair to engage with local installers and technicians for potential work	Engaging with local installers enhancing local workforce.

#### 5.4.1 Community feedback on the processes

Analysis of the interviews and survey results indicated positive community perceptions of the engagement processes employed in the Heyfield microgrid project. Notably, 85%

of survey respondents reported an increased understanding of microgrids following the project's community engagement initiatives. Most respondents rated the community engagement processes favourably (8-10), suggesting a high level of satisfaction with the implemented strategies.

An interviewee in the CRG group stated, while talking about the positive community engagement strategies:

*"I think, I think the team that we've got that are doing the feasibility study are fantastic. Yeah. And they've been so good at explaining everything to us and driving it along".*

**(CRG Interviewee 1).**

While the community engagement process was generally well-received, some interviewees expressed concerns and challenges. Certain members of the CRG voiced dissatisfaction with the allocation of project funds towards community engagement activities during the feasibility study, indicating a potential area of tension and differing priorities between stakeholders.

An interviewee while criticising the project stated:

*"I'd be interested to see where the money went, all those millions of dollars, or 1000s, or whatever, it was just some, you know, a spreadsheet of what was spent on each piece. Because really, it was obvious fairly early on, there wasn't going to be much of an outcome. On the ground, I mean, community education, I suppose. But only a few of us really stayed for the long haul. So it seems to be a lot of money spent. And, yeah, I just don't know, who's learning more, I guess the researchers are learning more than the community" (CRG Interviewee, 9).*

Throughout the project, the team employed various strategies to ensure effective communication and engagement. For example, when announcing techno-economic findings to the community, simple analogies were used to explain complex technical concepts in an accessible manner. The project team also conducted dedicated webinars

to convey the findings in a clear and comprehensive way. Recognising that the outcomes of the feasibility study might not be welcomed, the team facilitated open discussions with the members of a community reference group, focusing on potential future steps and exploring alternative energy solutions. Overall, the feedback received at the end of the project was largely positive, with community members acknowledging that they were provided with clear and accurate information. However, some remained unconvinced and expressed dissatisfaction with the outcome of the feasibility study, highlighting the ongoing challenges associated with managing diverse perspectives and expectations in community-based energy projects. This commitment to transparent communication and prioritising community needs, even when it involves conveying potentially disappointing outcomes, is a crucial aspect of the project's process-oriented approach.

Table 18 summarises the results captured from the semi-structured interviews from the CRG members, project team and the survey under the lens of the Technology, People, Place and Process framework.

*Table 18 Summary of the results under the lens of the Technology, People, Place and Process framework*

Framework element	Community perceptions and responses towards microgrids
Technology	<ul style="list-style-type: none"> <li>• Unfamiliar, complex technology</li> <li>• Lack of transparency of risks and benefits</li> <li>• Engagement strategies to increase understanding and awareness (Launch event, on-street engagement with local community, technical webinars and workshops, Business model workshops, Community fairs, Webinars and online reading material)</li> </ul>
People	<ul style="list-style-type: none"> <li>• Community Reference Groups for capacity building and inclusive decision-making.</li> <li>• Community Liaison Officers for capacity building and project facilitation.</li> <li>• Strategies for increasing community engagement (one on One engagement, school logo design competition, liaisons with schools with events, Posters and presentations, Meetings in the community)</li> </ul>

	centre, project video to be played at the key centers, community data dashboards installed in public places)
Place	<ul style="list-style-type: none"> <li>• Historical context of engagement and leadership on sustainable initiatives</li> <li>• Strong support for clean energy initiatives</li> <li>• A community centre that's an active hub for community participation</li> <li>• Historical context of an area that's traditional local industries (timber, coal) are transitioning.</li> </ul>
Process	<ul style="list-style-type: none"> <li>• Stakeholder engagement (nominating community liaison officers, formulating community reference groups)</li> <li>• Community engagement strategies (webinars and workshops for creating awareness and understanding of microgrids, face-to-face interactions and meetings, Interaction with schools and local installers, project videos and community dashboard)</li> </ul>

## 6. Discussion

This section provides a comprehensive discussion of the findings presented in the previous section, analysed through the lens of the Technology, People, Place, and Process framework. It offers an in-depth interpretation of the results, exploring their implications for community engagement in microgrid development and highlighting key insights relevant to policymakers, practitioners, and community stakeholders.

### 6.1 Engaging with people with different levels of energy literacy

A key challenge encountered by the project team was effectively engaging with community members who possessed varying levels of energy literacy. This challenge was compounded by the expectation that these individuals would actively participate in the decision-making process, shaping the project's trajectory and outcomes (Adams et al., 2022). Communicating complex technical concepts, such as microgrid functionalities and techno-economic feasibility assessments, to individuals with diverse backgrounds

and levels of understanding required careful consideration and innovative communication strategies.

The project team recognised the importance of investing time and resources in building community capacity and knowledge. This involved explaining fundamental concepts, the rationale behind the research, and the potential implications of microgrid implementation for the community. While allocating resources and effort to community education was crucial for informed decision-making, it also required significant dedication from both the project team and the community members involved.

Varying energy literacy levels within the CRG presented additional challenges as some technically proficient individuals perceived the simplification of concepts as a waste of time and resources, leading to tensions, consultation fatigue, and participant withdrawal. Furthermore, the extended duration of the feasibility study (three years) presented challenges for maintaining consistent community engagement. Participant attrition necessitated the ongoing integration of new members, requiring repeated explanations of fundamental concepts and project details. This continuous onboarding process proved resource-intensive for the project team and generated frustration among established members who possessed greater familiarity with the project's complexities.

This highlights critical challenges in community engagement for complex energy projects and reveals that community engagement is a resource-intensive process that requires dedicated time, funding, and expertise to ensure meaningful participation and informed decision-making. Moreover, effectively managing diverse energy literacy levels within the community is crucial for maintaining engagement, avoiding conflict, and ensuring that all participants feel valued and heard.

## 6.2 Navigating Complexity and Managing Expectations

The research findings revealed a strong community interest in microgrids and a high level of motivation in the local community to participate in the energy transition initiatives,

as indicated in section 5.3. However, the complexities associated with microgrid technology and project implementation presented significant challenges for community members. Understanding the technical aspects, economic feasibility, and regulatory implications of microgrids was demanding, even for individuals with prior knowledge of energy systems (Eklund et al., 2023). This complexity led to frustration among some participants, with some even withdrawing from the engagement process due to feeling overwhelmed. Consequently, employing accessible language, providing ample opportunities for dialogue and feedback, and actively addressing community concerns and misconceptions are essential strategies for fostering a shared understanding and facilitating informed decision-making. While the final outcome was to recommend that a microgrid solution should not be pursued, the high level of community engagement in the project contributed to more informed decision-making, enhanced trust, and stronger collaboration between stakeholders. It demonstrated that despite the inherent complexity, meaningful engagement can enhance community engagement, regardless of the final technical deployment.

Furthermore, managing expectations from the outset is crucial (Hicks & Ison, 2011). Clearly articulating the project's scope, objectives, and potential outcomes, including the distinction between feasibility studies and implementation projects, can help avoid misunderstandings and frustration among community members. In the case of Heyfield, some participants expressed disappointment when the feasibility study concluded that a microgrid was not the most viable option at that time. This disappointment stemmed from a perceived mismatch between their initial expectations and the project's outcomes. These expectations, such as the assumption that the feasibility study would lead directly to microgrid implementation, may have been partly shaped by early project communications, which some interpreted as implying a more immediate pathway to deployment. As a result, some community members questioned the rationale for investing resources in a feasibility study that did not produce tangible infrastructure. This

highlights the importance of clearly and transparently communicating the purpose, scope, and potential outcomes of each project phase, including the possibility that a microgrid may ultimately not be the most viable solution. By proactively managing expectations and addressing concerns as they arise, engagement practitioners can better navigate these challenges more effectively and maintain community support throughout the project feasibility process.

### 6.3 Balancing Community Empowerment and Technical Complexity in Engagement

While there is a normative objective to increase community participation in decision-making to enhance project legitimacy and social acceptance, the increasing complexity of energy systems presents challenges in ensuring that all community members possess the necessary knowledge and capacity to engage meaningfully (Hicks & Ison, 2011; Walker & Devine-Wright, 2008). It is essential to avoid simply "spoon-feeding" information to the community and instead promote a sense of ownership and empowerment by providing opportunities for genuine participation and informed decision-making.

However, expecting all community members to have a deep understanding of complex technical issues is unrealistic and potentially counterproductive. This raises the question of how to balance the desire for increased participation with the recognition that lay people may not possess the professional knowledge required to fully grasp all aspects of the project. Addressing this challenge requires a flexible approach to community engagement that acknowledges the diverse knowledge levels and capacities within the community. One strategy is to provide differentiated engagement opportunities that cater to varying levels of interest and expertise. This could involve offering introductory workshops and information sessions for those seeking a general overview, while also providing more in-depth technical workshops and forums for those interested in delving

deeper into specific aspects of the project. Additionally, creating opportunities for community members to share their knowledge and expertise, even if it is not directly related to energy systems, can promote a sense of ownership and value of their contributions.

Furthermore, it is essential to adopt a "small wins" approach, breaking down complex projects into smaller, more manageable phases with clear objectives and milestones. This allows community members to see tangible progress and feel a sense of accomplishment, even if the overall project is complex and long-term. Celebrating these small wins can help maintain momentum, build trust, and encourage continued participation. Ultimately, effective community engagement requires a flexible and adaptive approach that recognises the diverse needs and capacities of community members. By balancing the desire for increased participation with the need for clear and accessible communication, project developers can foster a sense of shared ownership and responsibility, leading to more successful and sustainable energy transitions.

## 6.4 Tailoring Engagement to People, Place, and Process

This research highlights the critical importance of considering the specific "people, place, and process" context when designing and implementing community engagement strategies for microgrid projects. The engagement strategies employed in Heyfield proved effective due to their alignment with the community's characteristics and the project's context. The community's openness to new technologies and its positive reception of webinars and online engagement activities enabled the successful implementation of these strategies. However, this research also highlights that a "one-size-fits-all" approach to community engagement is unlikely to be effective (Tahir et al., 2024a). This observation aligns with existing literature, which suggests that community engagement often extends beyond the boundaries of individual projects and varies significantly depending on the specific context and circumstances of each initiative

(Soutar et al., 2022). In communities with limited experience with renewable energy projects, different strategies may be required to foster understanding and acceptance. For instance, in communities where digital literacy or internet access is limited, alternative engagement methods, such as face-to-face workshops, community meetings, or printed materials, may be more appropriate. Similarly, in communities with a history of opposition to energy projects, building trust and addressing concerns through direct communication and relationship-building will be paramount. This may involve establishing ongoing dialogue with community leaders, facilitating opportunities for open and transparent communication, and actively involving the community in decision-making processes (Walker & Devine-Wright, 2008). By carefully considering the "people, place, and process" context and tailoring engagement strategies accordingly, project developers can enhance the effectiveness of their efforts and increase the likelihood of achieving positive project outcomes.

## 6.5 Situating Heyfield within the National Microgrid Context

While the Heyfield case study provides valuable insights into the interplay of people, place, and technology in shaping community engagement outcomes, it is important to situate these findings within the wider national landscape of microgrid development. Mathew et al. (2025) demonstrate that in remote Central Australia, solar microgrids remain uncommon, even where technical feasibility is established, due to excessive reliance on subsidised diesel generation, limited awareness of associated environmental costs, and socio-cultural resistance to change. These findings highlight the need to align community perceptions with institutional frameworks and norms in order to facilitate the broader adoption of microgrid technologies (Mathew et al., 2025).

Tahir et al. (2024), and Simon et al. (2024) in their analysis of a national cohort of microgrid feasibility studies funded under the Regional and Remote Communities Reliability Fund (RRCRF), found that although social and cultural drivers frequently underpin community engagement, many projects are impeded by persistent challenges,

including inadequate funding, limited energy literacy, consultation fatigue, and the complexity of participatory processes (Tahir et al., 2024b; Wright et al., 2024). These barriers align with the Heyfield experience, where high levels of community engagement were evident, but implementation was ultimately constrained by techno-economic factors. Given that the outcomes of RRCRF-funded projects remain pending, a review of all completed feasibility studies would be valuable to examine how technological, demographic, and locational factors have influenced microgrid feasibility and the associated community engagement processes.

Collectively, the insights indicate that scaling microgrid adoption across Australia requires more than context-specific, place-based engagement strategies; it necessitates coordinated institutional frameworks, supportive policy environments, and targeted capacity-building initiatives. The Heyfield case study reinforces that while socially embedded engagement is essential, its effectiveness depends on complementary measures, including sustained funding, regulatory certainty, and robust knowledge-sharing mechanisms, to convert local commitment into long-term energy system transformation.

## 7. Conclusion

This study highlights the complexities of community engagement in a microgrid feasibility study conducted within a rural Australian community, examining how community engagement strategies influence community perceptions towards microgrids. By employing the "Technology, People, Place, and Process" framework, this research analysed the factors influencing community perceptions towards microgrid initiatives, revealing key challenges and opportunities in the community engagement process.

The findings highlight the significance of tailoring engagement strategies to the unique characteristics of each community, recognising that a "one-size-fits-all" approach is ineffective and can lead to negative outcomes. Designing effective community

engagement requires an understanding of the local context, including social dynamics, energy literacy levels, and community expectations. Project stakeholders and community engagement practitioners should acknowledge the diverse range of knowledge within communities and avoid presupposing a uniform level of understanding regarding complex energy projects. Adopting inclusive engagement strategies that cater to varying backgrounds and literacy levels is crucial. Employing clear and accessible communication, devoid of technical jargon, ensures that all community members feel heard, understood, and empowered to participate meaningfully.

Community engagement strategies should be designed as a two-pronged approach: first, to educate and empower community members with the necessary knowledge and understanding of the project, and second, to facilitate their meaningful participation in the decision-making process. Despite the implementation of best practices in community engagement, challenges can arise due to the complex and dynamic nature of community interactions. Negative comments and opposition to projects can be mitigated through clear, transparent, and respectful engagement that acknowledges and addresses community concerns. The Heyfield case study exemplifies this, demonstrating that even when project outcomes diverge from initial community expectations, leading to frustration, proactive and resource-intensive engagement focused on the community's sustainable future helps maintain trust and support.

This research also reveals that community engagement is a long, complex, and resource-intensive process that demands consistent effort, transparency, and commitment from the project team as well as community groups. Furthermore, maintaining agility in community engagement activities is crucial to addressing emerging challenges and sustaining community interest in the project. While each community presents unique challenges, a deep understanding of the people and place factors highlighted in this study helps shape community perceptions of renewable energy technology.

Lastly, this research also reinforces that the social dimensions of microgrids are of immense importance, and addressing social acceptance is paramount to the project's progress. Community engagement, while challenging, is fundamental to ensuring community acceptance and long-term sustainability. As research on microgrids continues to grow in Australia and other regions around the world, these insights will be particularly beneficial for engaging rural and remote communities in meaningful ways.

## 8. References

- Adams, J., Kenner, A., Leone, B., Rosenthal, A., Sarao, M., & Boi-Doku, T. (2022). What is energy literacy? Responding to vulnerability in Philadelphia's energy ecologies. *Energy Research and Social Science*, 91(May), 102718. <https://doi.org/10.1016/j.erss.2022.102718>
- AEMO. (2023). *National Electricity Market (NEM)*. <https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem>
- Agterbosch, S., Meertens, R. M., & Vermeulen, W. J. V. (2009). The relative importance of social and institutional conditions in the planning of wind power projects. In *Renewable and Sustainable Energy Reviews* (Vol. 13, Issue 2, pp. 393–405). <https://doi.org/10.1016/j.rser.2007.10.010>
- Ansolabehere, S., & Konisky, D. M. (2014). *Cheap and Clean: How Americans Think about Energy in the Age of Global Warming*. MIT Press.
- Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*. <https://doi.org/10.1080/01944366908977225>
- Australian Bureau of Statistics. (2023). *Heyfield*. <https://abs.gov.au/census/find-census-data/quickstats/2021/SAL21179>

- Baron, J., & Herzog, S. (2020). Public opinion on nuclear energy and nuclear weapons: The attitudinal nexus in the United States. *Energy Research & Social Science*, 68, 101567. <https://doi.org/https://doi.org/10.1016/j.erss.2020.101567>
- Bergquist, P., Mildenberger, M., & Stokes, L. C. (2020). Combining climate, economic, and social policy builds public support for climate action in the US. *Environmental Research Letters*, 15(5). <https://doi.org/10.1088/1748-9326/ab81c1>
- Boudet, H. (2019). Public perceptions of and responses to new energy technologies. *Nat Energy*, 4, 446–455. <https://doi.org/10.1038/s41560-019-0399-x>
- Chalaye, P., Sturmberg, B., Ransan-Cooper, H., Lucas-Healey, K., Russell, A. W., Hendriks, J., Hansen, P., O'Neill, M., Crowfoot, W., & Shorten, P. (2023). Does site selection need to be democratized? A case study of grid-tied microgrids in Australia. *Energy Policy*, 183(April), 113854. <https://doi.org/10.1016/j.enpol.2023.113854>
- Chapman, A. J., & Pambudi, N. A. (2018). Strategic and user-driven transition scenarios: Toward a low carbon society, encompassing the issues of sustainability and societal equity in Japan. *Journal of Cleaner Production*, 172, 1014–1024. <https://doi.org/10.1016/j.jclepro.2017.10.225>
- Clean Energy Council. (2025). *Clean Energy Australia*. <https://cleanenergycouncil.org.au/getmedia/f40cd064-1427-4b87-afb0-7e89f4e1b3b4/clean-energy-australia-report-2025.pdf>
- Colvin, R. M., Witt, G. B., & Lacey, J. (2016). How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. *Energy Policy*, 98, 483–494. <https://doi.org/10.1016/j.enpol.2016.09.022>
- Creamer, E., Taylor Aiken, G., van Veelen, B., Walker, G., & Devine-Wright, P. (2019). Community renewable energy: What does it do? Walker and Devine-Wright (2008) ten

years on. *Energy Research & Social Science*, 57, 101223.  
<https://doi.org/10.1016/j.erss.2019.101223>

Cuppen, E. (2018). The value of social conflicts. Critiquing invited participation in energy projects. In *Energy Research and Social Science* (Vol. 38, pp. 28–32). Elsevier Ltd.  
<https://doi.org/10.1016/j.erss.2018.01.016>

de Abreu D'Aquino, C., Moretto, E. M., Zwartjes, N. M., Lenin da Silva, L., & Sachet, H. D. (2024). Design thinking methodology application to develop social acceptance questionnaire for renewable technologies. *Social Sciences & Humanities Open*, 10, 100912. <https://doi.org/https://doi.org/10.1016/j.ssaho.2024.100912>

Department of Climate Change, Energy, the Environment, and W. (2022). *Regional and Remote Communities Reliability Fund*. <https://www.energy.gov.au/government-priorities/energy-programs/regional-and-remote-communities-reliability-fund>

Dowd, A. M., Boughen, N., Ashworth, P., & Carr-Cornish, S. (2011). Geothermal technology in Australia: Investigating social acceptance. *Energy Policy*, 39(10), 6301–6307.  
<https://doi.org/10.1016/j.enpol.2011.07.029>

Dunning, J., & Turner, A. (2005). Community-owned wind farms—aspirations, suspicions and reality. *Power UK*, 131, 42–45.

Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2023). Energy Research & Social Science Understanding the community in community microgrids: A conceptual framework for better decision-making. *Energy Research & Social Science*, 104(August), 103260. <https://doi.org/10.1016/j.erss.2023.103260>

Eklund, M., Khalilpour, K., Voinov, A., & Hossain, M. J. (2024). Community microgrids: A decision framework integrating social capital with business models for improved resiliency. *Applied Energy*, 367. <https://doi.org/10.1016/j.apenergy.2024.123458>

- EM Rogers, A Singhal, & MM Quinlan. (2014). Diffusion of Innovations. *An Integrated Approach to Communication Theory and Research*, 432–448.
- Ernst, A., Biß, K. H., Shamon, H., Schumann, D., & Heinrichs, H. U. (2018). Benefits and challenges of participatory methods in qualitative energy scenario development. *Technological Forecasting and Social Change*, 127(September 2017), 245–257. <https://doi.org/10.1016/j.techfore.2017.09.026>
- Farla, J., Markard, J., Raven, R., & Coenen, L. (2012). Sustainability transitions in the making: A closer look at actors, strategies and resources. In *Technological Forecasting and Social Change* (Vol. 79, Issue 6, pp. 991–998). <https://doi.org/10.1016/j.techfore.2012.02.001>
- Farrelly, M. A., & Tawfik, S. (2020). Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renewable and Sustainable Energy Reviews*, 117(October 2019), 109491. <https://doi.org/10.1016/j.rser.2019.109491>
- Firestone, J., Hoen, B., Rand, J., Elliott, D., Hübner, G., & Pohl, J. (2018). Reconsidering barriers to wind power projects: community engagement, developer transparency and place. *Journal of Environmental Policy and Planning*, 20(3), 370–386. <https://doi.org/10.1080/1523908X.2017.1418656>
- Fischer, F. (2009). *Democracy and Expertise: Reorienting Policy Inquiry*. Oxford University Press.
- Flood, S., Cradock-Henry, N. A., Blackett, P., & Edwards, P. (2018). Adaptive and interactive climate futures: Systematic review of “serious games” for engagement and decision-making. *Environmental Research Letters*, 13(6). <https://doi.org/10.1088/1748-9326/aac1c6>
- Fombrun, C. J., Gardberg, N. A., & Barnett, M. L. (2018). Opportunity platforms and safety nets: Corporate citizenship and reputational risk. In *Limits to Stakeholder Influence: Why*

*the Business Case Won't Save the World* (pp. 12–33). Edward Elgar Publishing Ltd.  
<https://doi.org/10.1111/0045-3609.00066>

Fragniere, E., Sandoz, S., Abdenadher, N., Moussa, M., Di Marzo Serugendo, G., & Glass, P. (2023). Improving the Social Acceptability of Microgrids. *2023 IEEE Renewable Energy and Sustainable E-Mobility Conference, RESEM 2023*.  
<https://doi.org/10.1109/RESEM57584.2023.10236324>

Franziska Mey Anne Kallies, J. W., & Watson, M. (2023). Legitimizing energy transitions through community participation: Germany and Australia at a crossroad. *Globalizations*, 20(8), 1344–1362. <https://doi.org/10.1080/14747731.2022.2138261>

Galjak, M., & Budić, M. (2024). Public perceptions of fossil and alternative energy in Serbia: Between NIMBYism and nationalism. *Energy Policy*, 190.  
<https://doi.org/10.1016/j.enpol.2024.114137>

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). The Socio-Technical Dynamics of Low-Carbon Transitions. In *Joule* (Vol. 1, Issue 3, pp. 463–479). Cell Press.  
<https://doi.org/10.1016/j.joule.2017.09.018>

Giacovelli, G. (2022). Social Capital and Energy Transition: A Conceptual Review. *Sustainability*, 14(15). <https://doi.org/10.3390/su14159253>

Gordon, M., Schirmer, J., Lockwood, M., Vanclay, F., & Hanson, D. (2013). Being good neighbours: Current practices, barriers, and opportunities for community engagement in Australian plantation forestry. *Land Use Policy*, 34, 62–71.  
<https://doi.org/10.1016/j.landusepol.2013.02.005>

Guerrero M. Josep, & Kandari Ritu. (2021). *Microgrids: Modeling, Control and Applications*. Academic Press.

Hicks, J., & Ison, N. (2011). Community-owned renewable energy (CRE): Opportunities for rural Australia. *Rural Society*, 20(3), 244–255. <https://doi.org/10.5172/rsj.20.3.244>

- Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and Sustainable Energy Reviews*, 90(September 2017), 402–411. <https://doi.org/10.1016/j.rser.2018.03.040>
- Hu, R., & Han, X. (2023). Study on the path toward solutions for NIMBYism in China: A case study based on the qualitative comparative analysis method. *Heliyon*, 9(10). <https://doi.org/10.1016/j.heliyon.2023.e20269>
- Irvin, R. A., & Stansbury, J. (2004). Citizen participation in decision making: is it worth the effort? *Public Administration Review*, 64(1), 55–65.
- Jami, A. A., & Walsh, P. R. (2017). From consultation to collaboration: A participatory framework for positive community engagement with wind energy projects in Ontario, Canada. *Energy Research and Social Science*, 27, 14–24. <https://doi.org/10.1016/j.erss.2017.02.007>
- Jiménez-Estévez, G., Navarro-Espinosa, A., Palma-Behnke, R., Lanuzza, L., & Velázquez, N. (2017). Achieving resilience at distribution level: Learning from isolated community microgrids. *IEEE Power and Energy Magazine*, 15(3), 64–73. <https://doi.org/10.1109/MPE.2017.2662328>
- Kim, E. S., & Chung, J. B. (2019). The memory of place disruption, senses, and local opposition to Korean wind farms. *Energy Policy*, 131, 43–52. <https://doi.org/10.1016/j.enpol.2019.04.011>
- Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, 37(7), 1208–1221. <https://doi.org/10.1016/j.worlddev.2008.11.005>
- Koirala, B. P., Araghi, Y., Kroesen, M., Ghorbani, A., Hakvoort, R. A., & Herder, P. M. (2018). Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems. *Energy Research*

*and Social Science*, 38(December 2016), 33–40.  
<https://doi.org/10.1016/j.erss.2018.01.009>

Koirala, B. P., Koliou, E., Friege, J., Hakvoort, R. A., & Herder, P. M. (2016). Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems. In *Renewable and Sustainable Energy Reviews* (Vol. 56, pp. 722–744). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2015.11.080>

Komendantova, N., Riegler, M., & Neumueller, S. (2018). Of transitions and models: Community engagement, democracy, and empowerment in the Austrian energy transition. *Energy Research and Social Science*, 39(November 2017), 141–151. <https://doi.org/10.1016/j.erss.2017.10.031>

Kowalski, K., Stagl, S., Madlener, R., & Omann, I. (2009). Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis. *European Journal of Operational Research*, 197(3), 1063–1074. <https://doi.org/10.1016/j.ejor.2007.12.049>

Langham, E., Rutovitz, J., Smith, H., & Dwyer, S. (2021). *My Town Microgrid Conceptual Data and Analytical Framework*. [https://www.uts.edu.au/sites/default/files/2022-08/2.5 Conceptual Data %26 Analytical Framework\\_update.pdf](https://www.uts.edu.au/sites/default/files/2022-08/2.5%20Conceptual%20Data%20Analytical%20Framework_update.pdf)

LaPatin, M., Spearing, L. A., Tiedmann, H. R., Hacker, M., Kavvada, O., Daniélou, J., & Faust, K. M. (2023). Controversy in wind energy construction projects: How social systems impact project performance. *Energy Policy*, 176. <https://doi.org/10.1016/j.enpol.2023.113507>

Li, F. G. N., & Pye, S. (2018). Uncertainty, politics, and technology: Expert perceptions on energy transitions in the United Kingdom. *Energy Research and Social Science*, 37(September 2017), 122–132. <https://doi.org/10.1016/j.erss.2017.10.003>

- Lomax, J., Mirumachi, N., & Hautsch, M. (2023). Does renewable energy affect violent conflict? Exploring social opposition and injustice in the struggle over the Lake Turkana Wind Farm, Kenya. *Energy Research and Social Science*, 100. <https://doi.org/10.1016/j.erss.2023.103089>
- Loomis, C. P., & Tonnies, F. (2017). *Community and Society*. Taylor & Francis Group.
- Marinakis, V., Doukas, H., Xidonas, P., & Zopounidis, C. (2017). Multicriteria decision support in local energy planning: An evaluation of alternative scenarios for the Sustainable Energy Action Plan. *Omega (United Kingdom)*, 69, 1–16. <https://doi.org/10.1016/j.omega.2016.07.005>
- Martin-Martínez, F., Sánchez-Miralles, A., & Rivier, M. (2016). A literature review of Microgrids: A functional layer based classification. *Renewable and Sustainable Energy Reviews*, 62, 1133–1153. <https://doi.org/10.1016/j.rser.2016.05.025>
- Mathew, S., Bhatta, M., Baliva, G., Matthews, V., Zander, K. K., Joshy, A. L., Thakur, R., Joyce, C., Ford, L., Nagendra, S., Vasudevan, K., Cocking, J., & Vardoulakis, S. (2025). Why are solar microgrids not the norm in remote Central Australia? Exploring local perception on solar energy and health. *Journal of Cleaner Production*, 486. <https://doi.org/10.1016/j.jclepro.2024.144370>
- McCallum, D. B., & Santos, S. L. (1997). Comparative risk analysis for priority setting. *Human and Ecological Risk Assessment: An International Journal*, 3(6), 1215–1234. <https://doi.org/10.1080/10807039709383748>
- McGookin, C., Ó Gallachóir, B., & Byrne, E. (2021). Participatory methods in energy system modelling and planning – A review. *Renewable and Sustainable Energy Reviews*, 151(July). <https://doi.org/10.1016/j.rser.2021.111504>
- Međugorac, V., & Schuitema, G. (2023). Why is bottom-up more acceptable than top-down? A study on collective psychological ownership and place-technology fit in the Irish

- Midlands. *Energy Research and Social Science*, 96(December 2022).  
<https://doi.org/10.1016/j.erss.2022.102924>
- Miller, C. A., Iles, A., & Jones, C. F. (2013). The social dimensions of energy transitions. *Science as Culture*, 22(2), 135–148.
- Murunga, M., Ogier, E., Macleod, C., & Pecl, G. (2024). What drives public engagement by scientists? An Australian perspective. *Global Environmental Change*, 87.  
<https://doi.org/10.1016/j.gloenvcha.2024.102889>
- Ocelík, P., Lehotský, L., & Černoch, F. (2021). Beyond our backyard: Social networks, differential participation, and local opposition to coal mining in Europe. *Energy Research and Social Science*, 72. <https://doi.org/10.1016/j.erss.2020.101862>
- Olivares, D. E., Mehrizi-Sani, A., Etemadi, A. H., Cañizares, C. A., Iravani, R., Kazerani, M., Hajimiragha, A. H., Gomis-Bellmunt, O., Saeedifard, M., Palma-Behnke, R., Jiménez-Estévez, G. A., & Hatziargyriou, N. D. (2014). Trends in microgrid control. *IEEE Transactions on Smart Grid*, 5(4), 1905–1919.  
<https://doi.org/10.1109/TSG.2013.2295514>
- Osborne, C., Mayo, L., & Bussey, M. (2021). New frontiers in local government community engagement: Towards transformative place-based futures. *Futures*, 131(April), 102768.  
<https://doi.org/10.1016/j.futures.2021.102768>
- Oteman, M., Wiering, M., & Helderma, J. K. (2014). The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. *Energy, Sustainability and Society*, 4(1), 1–17.  
<https://doi.org/10.1186/2192-0567-4-11>
- Patrick Devine-Wright. (2011). Place attachment and public acceptance of renewable energy: A tidal energy case study. *Journal of Environmental Psychology*, 31(4), 336–343.  
<https://doi.org/10.1016/j.jenvp.2011.07.001>

- Perez-DeLaMora, D. A., Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. G. (2021). Roadmap on community-based microgrids deployment: An extensive review. *Energy Reports*, 7, 2883–2898. <https://doi.org/10.1016/j.egyr.2021.05.013>
- Planas, E., Andreu, J., Gárate, J. I., Martínez de Alegría, I., & Ibarra, E. (2015). AC and DC technology in microgrids: A review. *Renewable and Sustainable Energy Reviews*, 43, 726–749. <https://doi.org/10.1016/j.rser.2014.11.067>
- R. H. Lasseter. (2002). MicroGrids. *Proceeding of IEEE Power Engineering Society Winter Meeting*, 1, 305–308.
- Radtke, J., & Scherhauser, P. (2022). A social science perspective on conflicts in the energy transition: An introduction to the special issue. *Utilities Policy*, 78. <https://doi.org/10.1016/j.jup.2022.101396>
- Rowe, G., & Frewer, L. J. (2000). Public Participation Methods: A Framework for Evaluation. *Sage Journals*. <https://doi.org/10.1177/016224390002500101>
- Schelly, C. (2014). Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters. *Energy Research and Social Science*, 2, 183–191. <https://doi.org/10.1016/j.erss.2014.01.001>
- Schubert, D. K. J., Thuß, S., & Möst, D. (2015). Does political and social feasibility matter in energy scenarios? *Energy Research & Social Science*, 7, 43–54.
- Scovell, M., McCrea, R., Walton, A., & Poruschi, L. (2024). Local acceptance of solar farms: The impact of energy narratives. *Renewable and Sustainable Energy Reviews*, 189. <https://doi.org/10.1016/j.rser.2023.114029>
- Soshinskaya, M., Crijns-Graus, W. H. J., Guerrero, J. M., & Vasquez, J. C. (2014). Microgrids: Experiences, barriers and success factors. In *Renewable and Sustainable Energy Reviews* (Vol. 40, pp. 659–672). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2014.07.198>

- Soutar, I., Devine-Wright, P., Rohse, M., Walker, C., Gooding, L., Devine-Wright, H., & Kay, I. (2022). Constructing practices of engagement with users and communities: Comparing emergent state-led smart local energy systems. *Energy Policy*, 171. <https://doi.org/10.1016/j.enpol.2022.113279>
- Sovacool, B. K., Hess, D. J., Cantoni, R., Lee, D., Claire Brisbois, M., Jakob Walnum, H., Freng Dale, R., Johnsen Rygg, B., Korsnes, M., Goswami, A., Kedia, S., & Goel, S. (2022). Conflicted transitions: Exploring the actors, tactics, and outcomes of social opposition against energy infrastructure. *Global Environmental Change*, 73. <https://doi.org/10.1016/j.gloenvcha.2022.102473>
- Sovacool, B. K., Kivimaa, P., Hielscher, S., & Jenkins, K. (2017). Vulnerability and resistance in the United Kingdom's smart meter transition. *Energy Policy*, 109(August), 767–781. <https://doi.org/10.1016/j.enpol.2017.07.037>
- Suboticki, I., Heidenreich, S., Ryghaug, M., & Skjølsvold, T. M. (2023). Fostering justice through engagement: A literature review of public engagement in energy transitions. In *Energy Research and Social Science* (Vol. 99). Elsevier Ltd. <https://doi.org/10.1016/j.erss.2023.103053>
- Svobodova, K., Owen, J. R., Harris, J., & Worden, S. (2020). Complexities and contradictions in the global energy transition: A re-evaluation of country-level factors and dependencies. *Applied Energy*, 265. <https://doi.org/10.1016/j.apenergy.2020.114778>
- Tahir, F., Dwyer, S., & Kelly, S. (2024a). Embracing complexity: Microgrids and community engagement in Australia. *Energy Research & Social Science*, 118, 103811. <https://doi.org/10.1016/j.erss.2024.103811>
- Tahir, F., Dwyer, S., & Kelly, S. (2024b). Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program. *Energy Research and Social Science*, 109(July 2023), 103423. <https://doi.org/10.1016/j.erss.2024.103423>

- Toke, D. (2005). Explaining wind power planning outcomes: Some findings from a study in England and Wales. *Energy Policy*, 33(12), 1527–1539. <https://doi.org/10.1016/j.enpol.2004.01.009>
- Tricarico, L. (2021). Is community earning enough? Reflections on engagement processes and drivers in two Italian energy communities. *Energy Research and Social Science*, 72(December 2020), 101899. <https://doi.org/10.1016/j.erss.2020.101899>
- Ullman, A. N., & Kittner, N. (2024). Are global efforts coordinated for a Just Transition? A review of civil society, financial, government, and academic Just Transition frameworks. *Energy Research and Social Science*, 108. <https://doi.org/10.1016/j.erss.2023.103371>
- Upham, D. P., Sovacool, P. B., & Ghosh, D. B. (2022). Just transitions for industrial decarbonisation: A framework for innovation, participation, and justice. In *Renewable and Sustainable Energy Reviews* (Vol. 167). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2022.112699>
- Vaidya, A., & Mayer, A. L. (2016). Use of a participatory approach to develop a regional assessment tool for bioenergy production. *Biomass and Bioenergy*, 94, 1–11. <https://doi.org/10.1016/j.biombioe.2016.08.001>
- van Summeren, L. F. M., Wieczorek, A. J., Bombaerts, G. J. T., & Verbong, G. P. J. (2020). Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands. *Energy Research and Social Science*, 63(May 2019), 101415. <https://doi.org/10.1016/j.erss.2019.101415>
- Vargas, C., Corrales, J., Angelov, P., & Iglesias, J. (2019). Methodology for Microgrid/Smart Farm Systems: Case of Study Applied to Indigenous Mapuche Communities. *Advances in Intelligent Systems and Computing*, 893. [https://doi.org/10.1007/978-3-030-04447-3\\_6](https://doi.org/10.1007/978-3-030-04447-3_6)

- Volken, S. P., Xexakis, G., & Trutnevyte, E. (2018). Perspectives of Informed Citizen Panel on Low-Carbon Electricity Portfolios in Switzerland and Longer-Term Evaluation of Informational Materials. *Environmental Science & Technology*, 52(20), 11478–11489. <https://doi.org/10.1021/acs.est.8b01265>
- Waisman, H., Bataille, C., Winkler, H., & et al. (2019). A pathway design framework for national low greenhouse gas emission development strategies. *Nat. Clim. Chang*, 9, 261–268. <https://doi.org/10.1038/s41558-019-0442-8>
- Walker G, & Cass N. (2007). Carbon reduction, ‘the public’ and renewable energy: engaging with socio-technical configurations. *Area*, 39, 458–469.
- Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy*, 36(2), 497–500. <https://doi.org/10.1016/j.enpol.2007.10.019>
- Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663. <https://doi.org/10.1016/j.enpol.2009.05.055>
- Warbroek, B., & Hoppe, T. (2017). Modes of governing and policy of local and regional governments supporting local low-carbon energy initiatives; exploring the cases of the dutch regions of Overijssel and Fryslân. *Sustainability (Switzerland)*, 9(1), 1–36. <https://doi.org/10.3390/su9010075>
- Warneryd, M., Håkansson, M., & Karltorp, K. (2020). Unpacking the complexity of community microgrids: A review of institutions’ roles for development of microgrids. *Renewable and Sustainable Energy Reviews*, 121(December 2019). <https://doi.org/10.1016/j.rser.2019.109690>
- Warren CR, & McFadyen M. (2010). Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland. *Land Use Policy*, 27, 204–213.

- Wolsink, M. (2012). The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. In *Renewable and Sustainable Energy Reviews* (Vol. 16, Issue 1, pp. 822–835). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2011.09.006>
- Wolsink, M. (2018). Social acceptance revisited: gaps, questionable trends, and an auspicious perspective. In *Energy Research and Social Science* (Vol. 46, pp. 287–295). Elsevier Ltd. <https://doi.org/10.1016/j.erss.2018.07.034>
- Wolske, K. S., Stern, P. C., & Dietz, T. (2017). Explaining interest in adopting residential solar photovoltaic systems in the United States: Toward an integration of behavioral theories. *Energy Research and Social Science*, 25, 134–151. <https://doi.org/10.1016/j.erss.2016.12.023>
- Wright, S., Frost, M., Wong, A., & Parton, K. (2024). Australian microgrids: Navigating complexity in the regional energy transition. *Energy Research and Social Science*, 113. <https://doi.org/10.1016/j.erss.2024.103540>
- Wu, R., & Sansavini, G. (2020). Integrating reliability and resilience to support the transition from passive distribution grids to islanding microgrids. *Applied Energy*, 272(March), 115254. <https://doi.org/10.1016/j.apenergy.2020.115254>
- Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683–2691. <https://doi.org/10.1016/j.enpol.2006.12.001>
- Yin, R. K. (2009). *Case study research: Design and methods* (Vol. 5). Sage Publications.
- Zhou, Y., Panteli, M., Moreno, R., & Mancarella, P. (2018). System-level assessment of reliability and resilience provision from microgrids. *Applied Energy*, 230(April), 374–392. <https://doi.org/10.1016/j.apenergy.2018.08.054>

## 9. Appendix

### 9.1 Alternate initiatives explored in MyTown Microgrid Project

Initiatives explored	Energy bills	Reliability and resilience	Community involvement	Environmental benefit	Future proofing
<b>Microgrid</b>	x	✓	✓	✓	?
<b>On site options</b>	✓	✓	✓	✓	?
<b>Load flexibility &amp; control</b>	✓	✓	✓	✓	✓
<b>Community renewable generator</b>	x	x	✓	✓	x
<b>Community battery</b>	?	✓	✓	✓	✓
<b>Community retailers</b>	?	x	?	?	x
<b>Standalone power at critical sites</b>	x	✓	?	x	x

### 9.2 Interviewee details and characteristics

Interviewee	Characteristics and interests
<b>Interviewee 1</b>	Ecologist with an interest in sustainability and a pioneer in the installation of solar panels in Heyfield
<b>Interviewee 2</b>	A teacher with a curiosity about renewable energy technologies and was interested in the community projects.
<b>Interviewee 3</b>	Member of the Heyfield Community Resource Centre and an active part of the initiatives in the region.
<b>Interviewee 4</b>	Interested in renewable energy innovative technologies, with concerns about the fragility of the grid
<b>Interviewee 5</b>	Government employee with an environmental background. Participated in finding solutions for the benefit of the community.
<b>Interviewee 6</b>	Electrician with strong technical knowledge of the energy market.
<b>Interviewee 7</b>	Anthropologist with a strong role in community engagement around the project
<b>Interviewee 8</b>	Customer interest in energy and interested in climate change initiatives
<b>Interviewee 9</b>	Member of Heyfield community Resource Center, with strong interest in renewable energy project.
<b>Interviewee 10</b>	Landowner, with a farming background, interested in community projects.

### 9.3 Interview Script for CRG members

**Please introduce yourself, and when did you get involve in the project and the major driver/ what inspired you to be a part of CRG group?**

**CRG and microgrids:**

- What is the concept of microgrid or microgrid according to you?
- What were your initial thoughts of the project and how the project turned out?

**Community engagement and communication strategies:**

- Can you comment on the role of community reference groups in these projects and how important was the community engagement?
- Was CRG effectively included in the decision-making process?

- Since you are interacting with the community members, what was the community sentiment of the project in the beginning and now? Is there any change in the local awareness of the community, and the perception of microgrids in the community since the project started?
- What were the major issues this project was aiming to resolve and up to what level this feasibility study was able to achieve the desired goals and objectives?
- What challenges did you encounter as a CRG member in the project? and how did you cope up with that?

**Community batteries:**

What are the community perceptions on community batteries or behind the meter batteries? (some people have reservations so just wondering the community perception on this)

**Business model and the project ownership?**

What are your views on the ownership of the project?

**Conclusion:**

- What is the best possible energy solution for Heyfield according to you?
- Out of all the options, and technologies, what do you think is the best energy solution for Heyfield and why? (Community battery, load flex, microgrid, standalone systems) etc
- What are your future recommendations for the project and implementation studies?

**How would you review the overall progress of the project?**

- What went well in the project?
- What are the things that you wanted the team to improve?
- What's your perception of the project in the beginning as compared to that in the end?
- Looking back at the journey, what could've been done differently?
- What do you think could be done differently in terms of improving project management or communication?
- What advice do you give to someone who is starting the similar project in the future?
- Is there any change in your perception of the project from the start to finish)
- How does the ideal electricity system look like in Heyfield or what do you want to see?

**9.4 Survey Questionnaires for Heyfield community**

**Do you have a solar in your home?**

- Yes

- No

**Do you own a battery as well?**

- Yes
- No

**What kind of hot water system do you have?**

- Electric hot water
- Gas hot water system
- Heat pump

**Do you own or rent a house?**

- Own
- Rent

**Are there any energy monitoring devices installed in your premises?**

- Yes
- No

**Have you experienced the issues of power outage or voltage drop in the past years  
(before the beginning of the project)**

- Yes
- No

**If yes, what kinds of issues related to power supply (if any) have you experienced  
and how often?**

**Do you consider current electricity prices to be high or are you satisfied with the  
current electricity prices?**

- Very expensive
- Somewhat expensive
- I am okay with this.
- Not expensive
- Not expensive at all.

**Are you open to install new technologies to reduce the electricity cost in your  
house/business?**

- Yes

- No

**Are you interested in owning the energy assets?**

- Yes
- No

**If yes, what assets are you interested in?**

- Community battery
- Owning a solar system or a battery
- Diesel generator
- Microgrid

**How is your experience with your energy retailer?**

- Satisfied
- Somewhat satisfied
- Neutral
- Not satisfied
- Dissatisfactory

**How confident are you that your current energy set-up will be reliable and sustainable?**

- Extremely confident
- Somewhat confident
- Neutral
- Less confident
- Not confident at all

**What is your perception of renewable energy resources?**

**Which renewable energy technology interests you the most?**

**How does the ideal power system structure look like in Heyfield according to you?**

**Have you heard about the MyTown microgrid project?**

- Yes
- No

- A little

**Have you heard about the term “microgrid” before the MyTown Microgrid project?**

- Yes
- No

**What is the first word that comes to mind when you hear the term “microgrid”?**

**Should the microgrid be self-sustainable/island able?**

- Strongly agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Strongly disagree

**Has the MyTown microgrid project increased your awareness on local energy solutions? (Energy literacy)**

- Very much
- Somewhat
- Same as before
- Not much
- Not at all

**What are your expected outcomes at the end of the MyTown microgrid project?**

**(Rate from 1 to 5)**

- Cost effective electricity
- Reliable supply of electricity
- Resilience at the time of natural disasters
- Community ownership of the project
- Awareness in the local community

**Were the community decisions and outputs considered in the project?**

- Highly considered
- Somewhat considered
- Not considered completely
- Not at all considered

**How will you rate the community engagement strategies employed in the project  
(1 being the lowest and 10 being the highest)**

- Yes
- No

**How likely are you going to be involved in the future studies?**

- Highly likely
- Somewhat likely
- Neutral
- Less likely
- Not at all

**How will you rate the significance of the My Town microgrid project for your local  
community? (1 being the least significant and 10 being the highly significant)**

**How did you hear about the project?**

- Google
- Facebook
- Instagram
- Heyfield Community Center
- Community member (word of mouth)
- Newspaper/media reports
- School
- Others

**Are you willing to spend money on sustainable energy solutions for affordable  
electricity in the future or prefer the existing system?**

**Have you heard about the concept of load flexibility?**

- Yes
- No

**Have you heard of the energy efficiency and what comes in your mind with this  
word?**

**Are you willing to use hot water system from peak to off peak if it leads to savings on your electricity bills?**

- Yes
- No
- Maybe (depends on the incentive)

**When do you mostly run your hot water system?**

**Will you be willing to change the schedule of using hot water system for the possibility of cheaper electricity.**

- Yes
- No
- Maybe (depending on the incentive)

**What are your thoughts on changing your habits regarding the usage of hot water systems?**

**Will you trust the retailer or network provider to control your hot water systems or air conditioning for the cheaper electricity?**

- Yes
- No
- Maybe (depends on the incentive)

**Will you be willing to replace your current HVAC system with the more efficient one?**

- Yes
- No
- Maybe (depends on the incentive)

**Are you willing to install energy monitoring devices and control technologies?**

- Yes
- No

- Maybe (depends on the incentive)

**What are your thoughts on installing new technologies to increase electricity affordability and replacing the old ones?**

# Chapter 7

## Discussion



Microgrids for remote First Nations communities. Retrieved from ARENA  
<https://www.energynewsbulletin.net/energy-transition/news-articles/4518499/arena-backs-microgrids-remote-nations-communities>

## Chapter 7. Discussion

### 7.1 Introduction

This chapter synthesises the collective research findings of this thesis, encompassing published manuscripts, and provides a discussion around these findings in relation to the overarching research question and the four sub-questions established in Chapter 1 (see Introduction section 1.6). It is important to acknowledge that Chapters 4, 5, and 6 of this thesis, which comprise peer-reviewed journal articles, also each contain a dedicated discussion section. This chapter, however, differs in the way that it presents an overarching discussion framed around the research questions, drawing connections between the various results and emergent themes across all research undertaken.

This chapter is organised into five distinct sections, each addressing specific research questions. Section 7.2 presents an analysis of the overarching research question, synthesising the research findings to comprehend the role of the social dimensions of microgrids in the Australian energy transition. Section 7.3 examines the barriers and drivers influencing microgrid activities in Australia, directly linking the findings to the first research question. Section 7.4 focuses on the second research question, exploring the role of community engagement strategies in the planning and implementation of microgrids within Australian communities. Section 7.5 provides a discussion centred on the third research question, emphasising the implications of local community inclusion in decision-making processes in microgrid projects. Section 7.6 synthesises the findings about the social acceptance of microgrids, thereby addressing the fourth research question regarding the role of community engagement in enhancing social acceptance or generating conflicts. Finally, Section 7.7 concludes the chapter with a summary of the discussions related to the research questions.

## 7.2 Microgrids and their role in energy transition

This section provides a discussion of the findings in relation to the overarching research question, which examines how a sustainable transition framework can guide the advancement of microgrids in Australia, highlighting the pivotal role of community engagement. As stated in Chapter 3 (see section 3.5.3), the sustainable transition framework, Multi-Level Perspective was the theoretical framework selected for this thesis. Utilising a socio-technical lens under a multi-level perspective, this section analyses how microgrids are important to the advancements of microgrids in the Australian energy transition, with a focus on the importance of social dimensions and community engagement.

Figure 41, adopted from Geels (2002), represents the evolution of microgrids within the broader energy transition, framed within the Multi-Level Perspective (MLP) framework. It illustrates how various socio-technical factors interact across different levels, such as macro-level (landscape), meso-level (regime), and niche (innovation) over time, leading to the potential transformation of the energy system. Moreover, Figure 41 represents the role of the social dimensions of community engagement as an integral research area necessary for the integration of microgrids from niche into the existing regime.

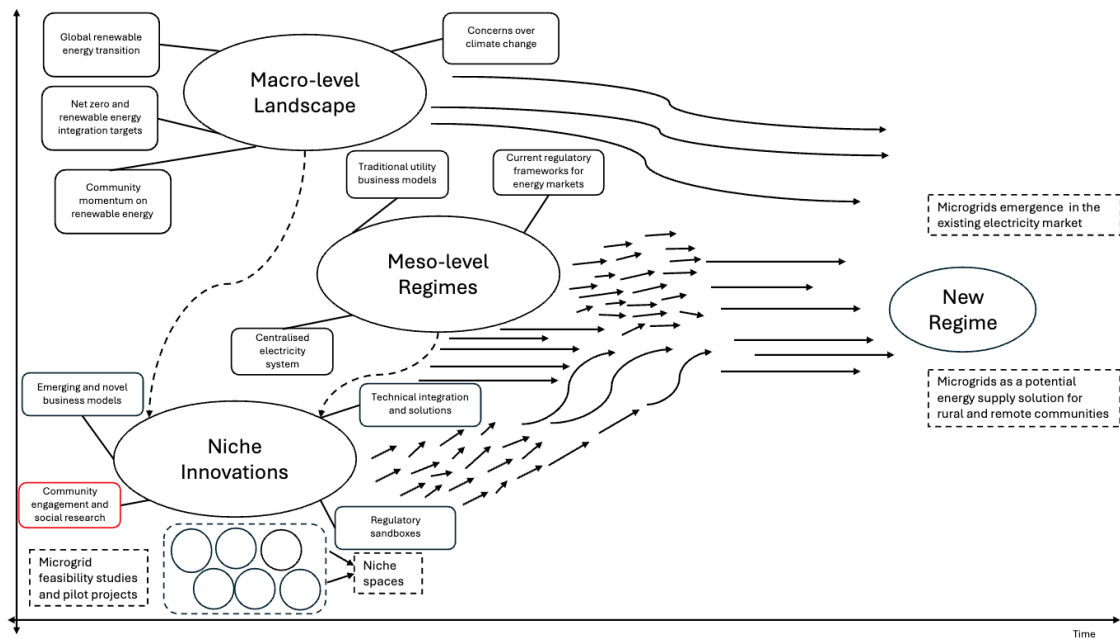


Figure 41 Multi-Level Perspective in relation to the Microgrids in Australia. Adopted from (Geels, 2002).

The macro-level landscape represents the broader external trends and overarching forces influencing the energy transition (Geels et al., 2017). These trends create pressure on the existing meso-level regimes, prompting the need for change. In the Australian context, as stated in Chapter 3 (section 3.2), one of the primary macro-level pressures is the global renewable energy transition, driven by international commitments and policy shifts towards cleaner and more sustainable energy sources. Governments and global organisations have set ambitious targets to reduce carbon emissions and phase out fossil fuels, reinforcing the need for transformation within national energy systems. This has prompted the Australian government to invest in renewable energy resources, shifting from centralised energy systems to decentralised and decarbonised energy systems. The initiatives undertaken by the Australian government in this regard have been stated extensively in Chapter 1 (see section 1.4). Additionally, net-zero targets at both national and state levels further accelerate decarbonisation efforts, pushing energy markets towards low-carbon alternatives. Another significant factor, as seen from the figure, is the growing community momentum on renewable energy. Public awareness towards renewable energy initiatives has increased significantly, with communities

advocating for more sustainable energy solutions (see section 1.5). This shift in societal attitudes places additional pressure on policymakers and energy providers to transition towards innovative clean energy systems (such as microgrids) that align with environmental and social expectations. Besides, the increasing frequency and intensity of climate-related disasters, such as wildfires, floods, and extreme heat events, underscore the urgent need for sustainable energy alternatives. As this landscape pressure intensifies, it will destabilise the existing energy regime, creating openings for alternative energy solutions such as microgrids. These landscape pressures not only push for the adoption of cleaner technologies but also encourage institutional and regulatory reforms that facilitate the integration of decentralised energy systems, ultimately fostering a more resilient and sustainable electricity infrastructure.

The meso-level regime encompasses the dominant structures, institutions, and business models that represent the incumbent energy system. Unlike the macro-level landscape, which introduces external pressures, the meso-level regime is where established energy practices, market dynamics, and policy frameworks are deeply entrenched, making transitions slow and complex. A critical component of the meso-level regime is traditional utility business models, which rely on centralised generation and large-scale electricity distribution networks. This structure has historically dominated energy markets, favouring economies of scale and long-established methods of energy transmission. Closely tied to this are current regulatory frameworks for energy markets, which govern electricity production, distribution, and consumption. These regulatory systems are designed around centralised energy models and often struggle to accommodate decentralised energy solutions such as microgrids. Another key feature of the meso-level regime is the centralised electricity system, which continues to rely heavily on large-scale fossil fuel generation and traditional grid-based distribution. Despite increasing efforts to integrate renewable energy, the dominance of fossil fuels in electricity markets has slowed the transition toward cleaner alternatives. However, ongoing technical integration

and solutions aim to bridge this gap by facilitating the adoption of renewable and decentralised technologies within the existing system. These efforts include advancements in grid modernisation, battery storage, and smart energy management (see section 1.2).

The arrows flowing from the macro-level landscape to the meso-level regime in the diagram illustrate how external pressures such as climate change policies and net-zero commitments are placing stress on the centralised electricity regime, pushing it toward transformation. However, as seen in real-world energy transitions, resistance to change remains strong, emphasising the crucial role of niche innovations, which act as disruptors by introducing alternative energy models that can eventually reshape the dominant system. By challenging existing market structures and proving the viability of decentralised solutions, niche innovations like microgrids have the potential to gradually influence and transform the meso-level regime.

The niche-level innovations represent innovative spaces where radical new solutions, such as microgrids, are developed, tested, and refined before they can be integrated into the broader energy system. Unlike the meso-level regime, which operates on larger structural and policy levels, niche innovations provide a protected environment for experimentation, allowing novel technologies and business models to evolve without immediate constraints from existing regulatory and infrastructural barriers. These innovations are essential for disrupting the incumbent centralised energy regime, as they introduce alternative solutions that have the potential to transform the dominant system over time (see section 3.4).

The research findings reveal that currently, microgrids occupy a niche position within the Australian energy transition discussion. One of the primary niche activities includes microgrid feasibility studies and pilot projects, which serve as initial testing grounds for microgrids in select locations. These trials are often conducted on university campuses, research institutions, and rural communities, where microgrids are evaluated for their

technical, economic, and social viability. A crucial aspect of research on microgrids is community engagement and social research, which focuses on understanding how communities perceive, accept, and interact with microgrids. Given that microgrid adoption is not solely a technical challenge but also a social one, research in this area helps identify barriers to acceptance, stakeholder concerns, and strategies to enhance engagement. The nurturing of microgrids in niche spaces allows collaborative innovation hubs to refine and advance microgrid technologies by providing knowledge sharing between researchers, policymakers, industry experts, and local communities. The arrows flowing from niche innovations into the meso-level regime illustrate the gradual scaling-up process of microgrids. As pilot projects and feasibility studies demonstrate technical reliability, economic feasibility, and social acceptance, microgrids begin influencing the dominant energy regime, leading to broader adoption and integration. This process is incremental but transformative, as successful niche experiments gain momentum, challenge the status quo, and ultimately contribute to systemic energy transition.

Therefore, landscape pressures are generating opportunities for microgrids to disrupt the existing energy regime and contribute to systemic change. However, as Figure 41 illustrates, comprehensive research across all facets of microgrid development, including their social dimensions, is crucial for facilitating their integration into the dominant regime. Despite extensive research on the techno-economic aspects of microgrids (see Chapter 2, section 2.1), their full integration into the dominant Australian energy regime remains unrealised, with one of the reasons being a lack of research on the social dimensions, community perceptions and understanding of social acceptance around microgrids

In summary, the research reveals that the confluence of landscape pressures in Australia and ongoing niche innovations in microgrid technology is likely to make them a suitable solution for rural and remote communities. Recent microgrid funding programs and policy initiatives have been recognised as important initiatives in nurturing and enhancing more

research on microgrids (See Chapter 1 Section 1.3). The MLP framework has successfully guided the advancement of microgrids in Australia, highlighting the role of social dimensions and community engagement in pushing microgrids from niche spaces to part of the existing regime. The subsequent sections of this chapter will analyse the emergent findings in relation to the research questions, elucidating how the research has addressed these inquiries and highlighting the emergent themes and their connections to the overarching research objectives.

## 7.3 Microgrid Drivers and Barriers

Research Question 1 explores the major barriers and opportunities identified in microgrid-related studies in Australia and examines how these findings align with existing literature. Chapter 4 provides a comprehensive response to this question, and this section offers additional analysis and discussion directly related to Research Question 1.

### 7.3.1 Microgrid – a concept with diverse interpretations

The research has revealed that microgrids have diverse interpretations and definitions, representing their inherent flexibility and adaptability to varying contexts (see Chapter 4, section 2.1). Australian government agencies have deliberately adopted broad definitions of microgrids to include various technical configurations and commercial models, ensuring flexibility and avoiding restrictions that could hinder adoption. The diverse interpretations of microgrids also reflect the nascent stage of the microgrid market in Australia. As renewable microgrids are still evolving as widely adopted energy solutions for rural and remote areas, their definitions are shaped by ongoing technological advancements, regional energy demands, and evolving regulatory structures (see Chapter 4, section 2.2). While this variability highlights the adaptability of microgrids to diverse conditions, it also complicates efforts to establish standardised regulatory and technical guidelines. For instance, regulators struggle to develop

consistent policies when the term "microgrid" encompasses everything from small, isolated systems in remote communities to advanced grid-connected systems for commercial and industrial precincts in urban areas (see Chapter 4 section 2.2).

Moreover, this definitional inconsistency extends to academic and policy dialogues, where it can misdirect research priorities and funding allocations. Projects described as "microgrids" may vary significantly in scope and purpose, making it challenging to compare outcomes, share best practices, or evaluate their scalability. The findings from the thesis have also revealed that stakeholders, including policymakers, community leaders, and technical experts, may interpret the term "microgrid" differently, depending on their backgrounds and priorities (see Chapter 4, section 4.1). This ambiguity potentially creates unrealistic expectations among communities, policymakers, and investors. For instance, communities engaged in feasibility studies might expect microgrids to provide energy independence or cost savings for the whole community without fully understanding the technical and financial complexities involved in the implementation. Policymakers and project developers, on the other hand, make sure that microgrids are technically and financially viable solutions for the local community. This variability in understanding microgrid deliverables and objectives necessitates effective community engagement during project planning and execution to avoid delays, frustration, and, in some cases, project failures. Research findings have revealed that a community's interpretation of microgrids varies significantly compared to the interpretation by the researchers (see Chapter 6, section 5.1). Figure 42 shows a two-word cloud showing the perception of microgrids in the academic community and the local community from one of the case studies (extracted from Chapter 4 section 4.1 and Chapter 6 section 5.1).



A) Word cloud by Heyfield community members



B) Word cloud by academics and industry professionals

*Figure 42 Comparative Analysis of Microgrid Interpretation*

The comparative analysis of the word clouds representing perceptions of microgrids among academics and the community reveals notable differences and some overlapping themes. The public's perception, as illustrated in the word cloud on the left, emphasises practical and tangible benefits. Keywords such as "affordable," "local," "small," "sharing," and "solar" reflect a focus on cost-effectiveness, localised impact, and environmental sustainability. Furthermore, terms like "clean" and "renewable" demonstrate an interest in the environmental advantages of microgrids and their potential to contribute to clean energy solutions. However, the presence of terms like "unsure" and "fantastic" highlights the coexistence of optimism and uncertainty regarding microgrids. This suggests that while the public recognises the potential benefits, a degree of scepticism or ambiguity persists regarding their functionality and implications. This finding underscores the importance of clear communication and public education initiatives to address knowledge gaps and foster a more comprehensive understanding of microgrid technology among the public.

In contrast, the academic word cloud reflects a more technical and systems-oriented perspective. Terms such as "islandable," "network," "connected," "generation," and

"resilience" emphasise the technical and operational dimensions of microgrids. Academic discourse also incorporates specialised terminology like "intelligently," "critical feeders," and "capabilities," highlighting priorities related to system design, optimisation, and technological innovation. Furthermore, the prevalence of terms such as "isolated" and "standalone" points to a specific interest in microgrid autonomy and their capacity for independent operation. This focus on operational reliability and efficiency aligns with academia's interest in advancing knowledge and innovation in microgrid technology, often prioritising technical advancements and system optimisation.

This comparative analysis reveals key interpretative differences between the perspectives of academics and community members regarding microgrids. While community members prioritise practical and community-centric benefits, such as affordability and localised environmental impact, academics delve into technical specifications and system-level attributes, including resilience, efficiency, and grid integration. This divergence is further reflected in the contrasting language employed by each group, with the community utilising accessible and relatable terminology, while academics rely on more technical and specialised language.

Despite these differences, both groups recognise the importance of the reliability and resilience offered by microgrid systems, albeit from different perspectives. For community members, resilience may be associated with basic services such as continuity of food refrigeration during power outages or extreme weather events. In contrast, academics or industry focus on technical resilience, encompassing system stability, operational efficiency, and the seamless integration of consumer energy resources. These findings accentuate the importance of bridging the gap between technical expertise and community perspectives in microgrid development. Effectively managing community expectations and fostering support for microgrid initiatives necessitates a deliberate and collaborative approach to engagement.

Employing accessible communication strategies that translate technical concepts into readily understandable language is needed. This entails providing opportunities for meaningful dialogue and feedback and actively incorporating community priorities into project design and implementation. By ensuring that the voices of residents are heard and valued, project developers can foster a sense of shared ownership and responsibility, facilitating the development of microgrid solutions that align with both technical feasibility and community needs. To further bridge the gap between technical expertise and community perspectives, policymakers, project stakeholders, and communities should actively collaborate to address public concerns, such as cost-effectiveness and localised benefits, while integrating academic insights into the promotion of reliable and efficient microgrid systems.

Thus, clearer and more consistent definitions of microgrids create consensus and bridge the gap of expectations between the project team and the community. Communities participating in microgrid projects would benefit from simplified and consistent messaging that elucidates the capabilities, potential benefits, and limitations of microgrid technology. This shared understanding would also enable policymakers to design more effective funding programs and regulatory frameworks that support the successful implementation and integration of microgrids within the broader energy system.

### 7.3.2 Indigenous Communities and Microgrids: Navigating Opportunities and Obstacles

Given that Research Question 1 addresses the barriers and drivers inherent in Australian microgrid projects, the analysis of the findings provides an opportunity to specifically examine the challenges and opportunities facing First Nations communities in relation to microgrid development. This section focuses on the unique barriers and opportunities within the context of First Nations communities, aiming to inform equitable and sustainable microgrid implementation that respects their distinct needs and aspirations.

This analysis is based on the findings presented in Chapters 4 and 5, complemented by additional desktop research.

A significant portion of Australia's Aboriginal and Torres Strait Islander population (approximately 60%) resides in regional and remote areas, with 43.8% of the population living in Regional Australia, whereas 15.4% of the population resides in remote communities (Australian Bureau of Statistics, 2021). Notably, 45% of ongoing microgrid projects under the RRCRF funding were being undertaken in Indigenous communities (Department of Climate Change, Energy, the Environment, 2022). There has been an increasing trend in funding allocation regarding renewable energy projects in First Nations communities, with programs increasingly prioritising First Nations projects. For microgrids, for example, the Australian Renewable Energy Agency (ARENA)'s Regional Microgrid Pilots Program has dedicated a substantial portion of its funding (approximately AUD 75 million, representing 70% of the total program budget) to projects benefiting Indigenous communities. This section detailed the barriers associated explicitly with the First Nation communities, providing guidance for the project managers and community engagement practitioners planning to undertake microgrid projects in these communities.

#### [7.3.2.1 Land ownership and legal issues](#)

A key finding of Chapter 4 highlights a critical, yet often neglected, barrier influencing microgrid project development within First Nation communities: land tenure and ownership (see Chapter 4, Section 4.3). Lands targeted for renewable energy infrastructure development frequently exist not as conventionally defined private property but as integral components of Indigenous territories. In some cases, substantial tracts of land may be held collectively by a few families or community leaders whose consent and active participation are essential for project viability. Unlike conventional private land ownership, Indigenous lands possess profound cultural, spiritual, and social significance, extending beyond mere economic value. This necessitates not only obtaining consent

but also ensuring community involvement throughout the project lifecycle, promoting a sense of ownership and ensuring alignment with community benefit. Developers must acknowledge the historical and ongoing relationship between First Nations peoples and their lands. Implementing transparent and inclusive engagement processes is crucial for ensuring community-driven projects that embody principles of social justice, self-determination, and equitable outcomes.

### 7.3.2.2 Leadership issues in the Indigenous communities

Issues related to community leadership in First Nations communities have also emerged and are being considered as the major barrier in microgrid adoption. This includes constant change in leadership, lack of organisational structure and priority settings (see Chapter 4, section 4.3.3).

Challenges related to community leadership within First Nations communities represent a significant impediment to microgrid adoption. These challenges include frequent leadership transitions, a lack of established organisational structures, and fluctuating priorities. The dynamic nature of leadership within First Nations communities presents a key obstacle. As traditional leadership structures evolve, community priorities shift, developmental visions diverge, and previously agreed-upon decisions may be revisited. These changes can disrupt project continuity, requiring stakeholders to re-establish relationships, redefine project objectives, and renegotiate community requirements with new leadership.

Furthermore, community leaders in First Nations communities often prioritise pressing, immediate needs, such as housing shortages, healthcare access, education, and economic development, which can overshadow long-term energy planning, despite its acknowledged importance. Even when communities recognise the financial burden and environmental unsustainability of diesel generators, the transition to cleaner, more cost-effective microgrid solutions may not be a primary focus of the local leaders. This misalignment of priorities has, in some cases, resulted in the cancellation of microgrid

projects due to a lack of project backing from community leaders. This highlights the competing demands on community leadership and the challenges of integrating long-term infrastructure projects into existing priorities.

A further obstacle to microgrid implementation in Indigenous communities is the absence of a well-defined organisational structure or governance model. Often, a clearly designated entity with whom developers can engage is lacking, hindering initial collaboration efforts. This absence of organisational infrastructure creates challenges for developers seeking community input and participation. Without a formal governance framework, project processes can become informal and reliant on ad-hoc discussions, potentially failing to represent the broader community's needs and priorities.

Therefore, effective leadership within First Nations communities is crucial for successful microgrid projects. Such leadership is characterised by individuals with a vision who recognise energy as a critical issue and provide consistent, long-term guidance. Strong community leaders can establish the foundation for an organised governance structure, ensuring accountability, equitable representation, and a clear framework for meaningful community participation and decision-making. Project managers and community engagement professionals must be mindful of these leadership dynamics and adapt their engagement strategies accordingly to facilitate project advancement.

#### 7.3.2.3 Knowledge gaps in microgrid implementation in Indigenous communities

A significant challenge stems from the limited availability of knowledge-sharing platforms and the relatively small number of existing microgrid projects within Indigenous communities in Australia. This lack of readily accessible information creates a significant hurdle for stakeholders undertaking projects in these communities (see Chapter 5, section 4.3.2). This limited uptake can be attributed to the complexities inherent in engaging with Indigenous leadership and navigating diverse community aspirations and land ownership issues. Without a robust repository of shared experiences and lessons

learned, stakeholders are often left to address these multifaceted challenges with limited guidance, potentially leading to project delays, cost overruns, or even project abandonment. This knowledge gap underscores the need for greater investment in documenting and disseminating information regarding successful microgrid implementations in Indigenous communities.

#### 7.3.2.4 Funding issues

Funding constraints and the complexities of funding applications pose significant barriers to Indigenous communities' independent pursuit of microgrid projects, as highlighted by the interviewees (see Chapter 4, section 4.3.2). Even when funding opportunities exist, access remains highly competitive, often requiring intricate application processes that exceed the capacity and expertise of many Indigenous communities. Furthermore, these processes frequently fail to consider the unique contexts and needs of First Nations communities, further limiting their participation. While federal and state governments in Australia are developing new funding streams and grants specifically targeting Indigenous communities (e.g., the Regional Microgrid Pilot program, which allocates AUD 75 million of its AUD 125 million budget under Stream B for projects in First Nations communities), these initiatives must address the underlying challenges of application complexity and ensure accessibility for Indigenous applicants.

#### 7.3.2.5 Energy literacy issues

A clear disparity in energy literacy among First Nation communities emerged from interviews with those involved in microgrid projects (see Chapter 4, section 4.3.3). Some communities demonstrated a strong understanding of energy concepts, while others possessed limited knowledge of renewable energy resources, including basic familiarity with solar and battery technologies. This disparity complicates effective community engagement. Technical documents, contractual agreements, and feasibility study findings are often presented in complex legal or technical language, proving difficult for community members to fully comprehend. Without appropriate translation, cultural

mediation, and accessible visual or oral communication methods, community consent may be based on incomplete or inaccurate information. Addressing these literacy gaps requires culturally sensitive communication strategies and capacity-building initiatives that empower Indigenous communities with the knowledge and skills necessary for active participation in decision-making processes. Engaging with local schools represents a promising intergenerational approach, educating children while indirectly reaching other community segments. Early identification and assessment of energy literacy levels are essential for project managers and practitioners to develop targeted and effective community engagement strategies.

#### 7.3.2.6 Lack of access to smart meters

The absence of granular energy consumption data in First Nations communities, largely due to the lack of smart meter infrastructure, presents a critical challenge for microgrid project implementation (see Chapter 4, section 4.3.4). Prepayment meters, commonly used in these communities, do not provide the detailed usage records necessary for effective energy planning. This data deficit extends beyond daily consumption patterns; even basic records of energy expenditure are often unavailable, let alone the granular data (e.g., 15-minute intervals) crucial for microgrid design and optimisation. Without smart meters or formal billing systems, understanding household energy consumption relies on indirect and often incomplete sources, such as power card purchase records from local stores. Cash-based prepayment systems further compound this issue, leaving no digital audit trail of energy transactions. Consequently, community members themselves often lack awareness of their own energy usage, hindering needs assessments and the identification of energy efficiency opportunities. This lack of data visibility significantly impedes the effective planning, implementation, and optimisation of microgrid projects. Addressing this challenge requires investment in appropriate metering infrastructure capable of capturing detailed energy usage data, while remaining culturally and contextually appropriate for remote Indigenous communities. The

introduction of such systems would not only enhance the feasibility of microgrid projects but also empower communities by providing valuable insights into their energy consumption and costs.

Microgrids offer significant potential for First Nations communities; however, successful integration necessitates a holistic approach that addresses land tenure complexities, navigates leadership dynamics, mitigates communication barriers, and alleviates funding constraints (see Chapter 4, section 4.3.5). Respectful, well-planned, and culturally sensitive engagement is paramount for realising this potential. Microgrid projects present a unique opportunity to empower First Nations communities in shaping their sustainable energy futures. These projects can serve as catalysts for workforce development, integrating community members into the burgeoning clean energy sector. By prioritising local talent, these initiatives can create employment opportunities for Indigenous installers, developers, technicians, and tradespeople, including Vocational Education Technology (VET) students and apprentices. This not only fosters economic growth within the community but also ensures local ownership and long-term sustainability of the projects.

To conclude this section, addressing research question 1 is paramount in advancing the understanding of the social dynamics surrounding microgrids, as it lays the groundwork for comprehending diverse viewpoints, challenges, and prospects associated with their development and adoption within Australian communities. As comprehensively explained in Chapter 4, the key drivers for microgrid adoption include energy resilience in the face of extreme weather events, such as bushfires, floods, and storms, energy reliability to operate independently in an islanded mode in case of an emergency or grid outage, and economic advantages, following reducing reliance on costly diesel generation, have been a strong motivating factor for feasibility studies (see Chapter 4, section 4.4). The major barriers were categorised using the PESTEL framework and have been explained extensively (see Chapter 4, section 4.5). However, descriptive

analysis of the research findings allowed a better understanding of microgrid interpretations from the perspective of project stakeholders and the local community, showing the significant gap in understanding and highlighting the need for community engagement to bridge this gap. The analysis provided an opportunity to explicitly look at the barriers and drivers in the First Nation communities, providing researchers and project stakeholders a starting point to initiate the project.

## 7.4 Community Engagement Strategies Facilitating Microgrid Implementation

This section analyses the findings in relation to Research Question 2, which investigates how community engagement strategies facilitate the planning and implementation of microgrids within diverse Australian communities. While Chapter 5 (Sections 4) provides a detailed examination of various community engagement strategies and their associated discussion points, this section focuses on analysing the findings of the overall thesis and the emergent themes aligned with Research Question 2.

### 7.4.1 Effective community engagement strategies and shifts in methodologies

While various engagement strategies are employed in microgrid studies, face-to-face interaction has consistently proven most effective (see Chapter 5, section 5.2). This approach promotes trust in the community and enhances rapport with local communities, facilitating direct and meaningful dialogue throughout the project lifecycle.

However, the COVID-19 pandemic significantly impacted community engagement strategies, necessitating a shift from traditional engagement methods to unconventional approaches, with a notable rise in the adoption of online tools and virtual platforms. Community engagement platforms like Zoom and Teams became essential for conducting meetings, webinars, and engagement activities. While these tools enabled

project continuity amid restrictions, they presented challenges in communities unfamiliar with or resistant to digital communication. Not all community members possess equal access to stable internet connections, appropriate devices, or the digital literacy required for effective online engagement. Consequently, project teams had to adapt by offering training sessions, providing guidance materials, and developing hybrid approaches to ensure inclusive participation. This shift in engagement dynamics posed challenges for older individuals and those with limited access to digital infrastructure, resulting in reduced participation. This experience emphasises the importance of adapting engagement strategies to specific community contexts, recognising that a one-size-fits-all approach is inadequate.

As the world transitions to post-pandemic realities, community engagement methodologies continue to evolve. Online technologies have become more sophisticated, and engagement professionals increasingly rely on hybrid approaches that combine online and in-person methods. Communities, too, are gradually adapting to this shift and becoming more familiar with new technologies. By blending traditional and modern engagement techniques, microgrid projects can ensure more inclusive and effective collaboration. This approach accommodates diverse needs and preferences while leveraging the benefits of emerging technologies. Ultimately, a flexible and adaptive approach to community engagement is crucial for fostering trust, building consensus, and ensuring the long-term success of microgrid projects.

#### 7.4.2 Enhancing Community Engagement Through Data Collaboration and Capacity Building

The findings presented in Chapter 5 underscore the critical role of data and capacity-building in facilitating effective community engagement within microgrid feasibility studies (see Chapter 5, section 4.11).

Collaboration between Distributed Network Service Providers (DNSPs), project teams, and local communities is essential for accessing electricity network data, which informed microgrid feasibility assessments in 80% of the projects examined. However, network data alone often proves insufficient, requiring supplementary sources such as retrofitted energy monitoring devices (utilised in 50% of projects) and smart meters (40%). This reveals a missed opportunity for DNSPs to engage communities more actively in the interpretation and application of energy data, a process that could enhance energy literacy and foster community ownership of energy transitions. Involving community members in discussions about energy data not only supports informed decision-making but also aligns with the broader goals of microgrid projects, which aim to promote energy autonomy and sustainability. By implementing transparent data-sharing practices and actively involving communities in data interpretation during feasibility studies, DNSPs and project teams can strengthen trust and collaboration, ultimately leading to more successful project outcomes. This participatory approach positions DNSPs as key enablers of community-driven energy transitions while ensuring the long-term viability of microgrid initiatives.

Furthermore, the findings reveal that extensive community engagement was significantly facilitated by funding from a national program supporting independently delivered microgrid feasibility projects (see Chapter 5, section 4.4). These grant-funded initiatives enabled project teams to adopt flexible and adaptive approaches across diverse and challenging contexts. Such funding programs are instrumental in building capacity and expertise among community engagement professionals at both individual and organisational levels. The skills and experience developed through these programs are essential for empowering rural and remote communities, ensuring they are actively involved and feel heard in the broader energy transition.

In conclusion, collaborative data engagement and capacity-building initiatives highlight the importance of holistic, well-supported approaches to community engagement in

microgrid projects. By combining transparent data practices with robust funding mechanisms, stakeholders can cultivate empowered, energy-literate communities that are integral to driving Australia's sustainable energy future.

### 7.4.3 Accelerating community engagement in microgrid projects

This section examines the factors that accelerate community engagement in regional and remote communities, focusing on specific elements introduced in Chapter 5 and Chapter 6, requiring further investigation. Central to successful engagement is the development of trust. As Putton (1996) highlights trust not only facilitates cooperation but also addresses scepticism and fosters long-term relationships between project teams and local communities. Misztal (1996) further emphasises trust's crucial role in cultivating mutual respect, promoting collaboration, and building social capital (Barbara Misztal, 1996). This is echoed by Walker et al. (2010), who identify trust as integral to achieving positive outcomes in community renewable energy projects (Walker et al., 2010), and Koirala et al. (2018), who recognise community trust as a key component of community energy projects (Koirala et al., 2018). Luhmann's work on trust further illuminates its function as a form of social capital that underpins collaboration, particularly in contexts where historical marginalisation or exploitation may have eroded trust in external entities (Luhmann, 1979). Building trust requires consistent effort to engage with communities in a manner that respects their values, traditions, and cultural norms, underscoring the importance of culturally sensitive and participatory approaches. Community engagement strategies are designed to develop trust with the community members, resulting in the successful implementation of microgrid projects (see Chapter 5, section 4.5).

Existing connections with community members, local councils, retailers, utilities, and network providers offer a valuable foundation for engagement. These relationships provide a starting point for collaboration, ensuring that projects build upon existing networks rather than starting from scratch. One effective strategy for cultivating trust is

appointing community engagement officers as representatives of the local community (see Chapter 6, section 4.1). These individuals possess an intrinsic understanding of the community's unique dynamics, enabling them to bridge the gap between the project team and the community. Conversely, nominating representatives without community endorsement can exacerbate distrust and hinder communication. Clear messaging is equally crucial for building trust and ensuring project success. Misinformation or ambiguity can create confusion about project goals, stakeholder roles, and expected outcomes. Transparent communication ensures community understanding of not only the project's objectives but also the roles and responsibilities of all stakeholders. Trust and clear messaging are intertwined; trust cannot be built without transparency, and transparency is ineffective without clarity. Together, these elements form the bedrock of successful community engagement, fostering collaboration and long-term project success.

Furthermore, the presence of community centres plays a vital role in accelerating engagement and dissemination activities. These centres serve as informal gathering spaces where community members discuss projects, exchange ideas, and contribute to project development. Project teams can leverage these spaces to conduct webinars, technical workshops, meet-and-greet events, and disseminate information through posters and other materials. This organic, word-of-mouth communication fosters a deeper understanding of the project, builds community support, and creates a positive project image.

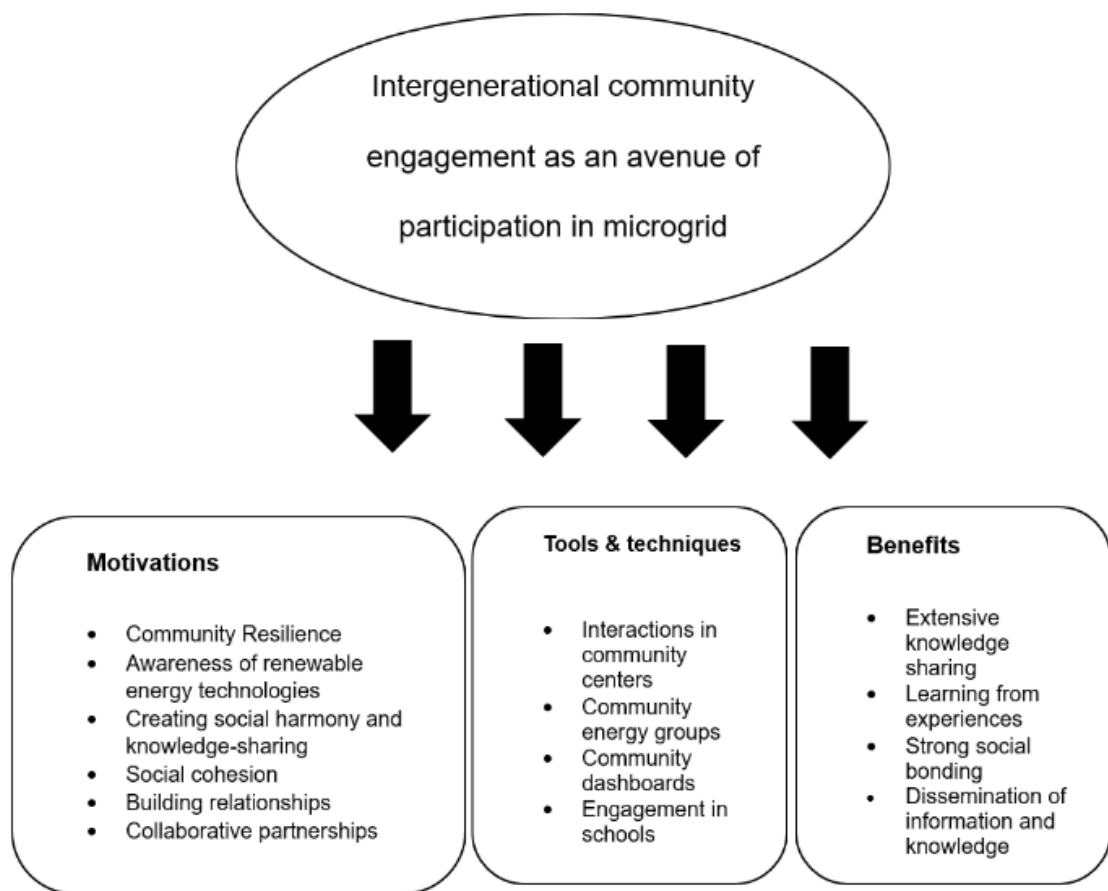
Strong, positive word-of-mouth communication significantly influences community perception and engagement with energy initiatives. Even community members lacking in-depth technical knowledge demonstrate support when they perceive that the project aligns with local values and prioritises collective well-being. This sense of shared identity, fostered by strong interpersonal networks and mutual trust, encourages community-wide support, regardless of individual energy literacy levels. When communities witness a

genuine commitment to improving local welfare, they are more likely to invest their time, resources, and goodwill, streamlining project development and fostering continued collaboration. Finally, community incentives, ranging from refreshments and meals to vouchers and raffle tickets, can effectively catalyse engagement. By providing tangible rewards, project stakeholders can stimulate participation in workshops and webinars, encouraging community members to learn more about the initiative. Incentives can also help reduce participant attrition, maintaining engagement throughout the project.

In conclusion, these factors collectively accelerate community engagement processes. Microgrid projects can cultivate strong community relationships by focusing on trust-building, clear communication, leveraging existing community spaces, fostering positive word-of-mouth, and providing incentives, leading to more successful and sustainable outcomes.

#### 7.4.4 Intergenerational engagement in the community

Chapter 5 revealed extensive community engagement activities aimed at promoting an understanding of microgrids. However, one strategy requiring further exploration is intergenerational engagement, which has proven successful in three case studies involving populations with diverse age demographics, including older adults and young children. This strategy suggests that engaging children with microgrids can lead to them conveying information to their parents, thereby disseminating knowledge throughout the community. This section will further analyse the potential of intergenerational engagement as a strategy for promoting microgrid adoption. Figure 43 shows the motivation, benefits and necessary tools for intergenerational community engagement.



*Figure 43 Model for Intergenerational Community Engagement*

Globally, the world is experiencing unprecedented demographic shifts, characterised by a significant rise in the ageing population. Crespo and Preez (2014) highlight that the global population over 60 is projected to nearly triple within the next 30 years, while the percentage of individuals under 14 years is expected to decline from 28% to 20% by 2050 (Crespo & du Preez, 2014). These trends are mirrored in Australia, where life expectancy has risen from around 51 years in 1900 to 81 years for males and 55 years to 85 years for females by 2023. This shift is primarily attributed to increased life expectancy and declining fertility rates (ABS, 2024).

Intergenerational engagement (IE) programs offer a targeted approach to community participation designed to bridge generational gaps and provide scalable resources and infrastructure (Hatton-Yeo, 2010; Lawrence-Jacobson, 2006). These programs foster collaboration and connection between older adults and younger generations, creating

opportunities for shared learning and mutual support. By encouraging intergenerational interaction, IE programs promote social inclusion, challenge stereotypes about ageing, and enhance the well-being of all participants. These initiatives are crucial for building cohesive and resilient communities that value the contributions of all age groups.

Despite the growing recognition of the importance of involving both younger and older people in renewable energy projects, Buffel et al. (2014) highlight that these age groups are often overlooked in decision-making processes. Research indicates that younger and older individuals are frequently denied opportunities to participate meaningfully in shaping project outcomes (Buffel et al., 2014). This phenomenon, referred to as the "paradox of neighbourhood participation," highlights how these groups, despite spending more time in their neighbourhoods compared to other age groups, are often excluded from decisions directly impacting their local environments.

#### 7.4.4.1 Intergenerational community engagement in microgrids

Intergenerational engagement strategies offer a valuable mechanism for addressing community engagement challenges in microgrid studies. By enhancing energy literacy and facilitating knowledge exchange between younger and older generations, these strategies foster a more inclusive and comprehensive understanding of renewable energy initiatives (National Seniors Australia, 2024). Involving both young people and older adults in educational activities, decision-making processes, and hands-on experiences cultivates a dynamic exchange of ideas, values, and practical insights (Play matters, 2024). Younger participants contribute enthusiasm, technological familiarity, and innovative thinking, while older community members offer wisdom, lived experience, and long-term perspectives. Integrating these generational strengths enables community energy initiatives to achieve deeper cultural resonance and establish a stronger foundation for long-term success.

The research has revealed the importance of intergenerational engagement, suggesting multiple initiatives to enhance interactions between the two generations. One of the key initiatives undertaken to engage children was a logo competition, where students were invited to design a logo for the microgrid project. This activity not only sparked excitement and curiosity among young participants but also provided them with an opportunity to develop a sense of ownership over the project. By integrating creative engagement methods, the project team ensured that younger generations could connect with the concept of microgrids in a fun and memorable way. Collaborating with educational institutions to engage students in renewable energy education represents a promising strategy. By partnering with teachers, administrators, and student groups, innovative initiatives can be implemented, such as integrating renewable energy concepts into the school curriculum. This approach provides children with sustained learning opportunities that align with broader educational goals, fostering a deeper understanding of sustainable energy principles and their practical applications.

Another engagement strategy involved recruiting a diverse mix of younger individuals and older community members into community reference groups. These groups served as a platform for intergenerational discussions, where different perspectives, experiences, and concerns could be shared. The inclusion of both younger voices and older, experienced stakeholders facilitated a more inclusive dialogue, allowing for a broader representation of community needs and expectations regarding microgrid implementation. This approach also fostered knowledge-sharing between generations, where older members contributed insights based on lived experiences while younger participants introduced new ideas and technological perspectives. Furthermore, project teams can establish collaborative partnerships with schools, transforming them into vital hubs for knowledge dissemination. By hosting demonstrations of energy monitoring devices, schools can provide students with tangible insights into energy consumption patterns, enabling them to visualise fluctuations and understand the concrete impacts of

renewable energy projects. Such demonstrations effectively translate abstract sustainability concepts into tangible learning experiences, fostering engagement and stimulating further exploration within both the school environment and the broader community. The provision of educational resources, such as "Community Energy Toolkits" containing accessible materials and interactive modules, can facilitate knowledge dissemination and intergenerational dialogue. These toolkits empower students to extend their learning beyond the classroom, sharing insights with older generations about community energy projects, microgrids, and their applications. Additionally, incorporating workshops and teamwork exercises can introduce students to renewable energy sources, fostering awareness of sustainable energy practices. Initiatives such as design competitions and site visits can cultivate student interest and provide real-world context for renewable energy systems. Moreover, integrating digital and physical engagement tools, such as community dashboards displayed in schools or community centres, can enhance the visibility and understanding of microgrid performance and benefits. Interactive hands-on activities, such as allowing children to play with solar panels, were introduced to create tangible learning experiences. By physically interacting with renewable energy technology, children gained a deeper understanding of how solar energy contributes to microgrid systems. This experiential approach encouraged an early interest in sustainable energy solutions, potentially influencing future generations to support and advocate for renewable energy transitions in their communities.

The use of personas and storytelling has also proven to be an effective approach for conveying complex renewable energy concepts to younger generations, as demonstrated in some microgrid projects. By simplifying ideas such as community energy, energy efficiency, microgrids, virtual power plants (VPPs), and stand-alone photovoltaic systems (PVs), personas and stories make these concepts more accessible and relatable to students. This approach not only enhances understanding but also

sparks curiosity and engagement, empowering younger audiences to grasp the principles of renewable energy and their practical applications. Installing community dashboards in schools and other high-traffic areas raises awareness within the community and fosters conversations about ongoing renewable energy projects. For students, seeing dashboards in their schools reinforces classroom lessons, while sharing these insights with family members extends learning into the broader community. Over time, this cycle of intergenerational knowledge sharing and reinforcement builds a more informed and adaptive community, enabling them to thrive within the evolving renewable energy landscape.

Older adults play a vital role in this process as well, contributing their wisdom, lived experiences, and insights into community needs. Their participation in advisory committees, community events, and knowledge-sharing initiatives ensures that decision-making processes reflect a broader range of perspectives. Activities like community fairs, which bring together multiple generations, provide an ideal platform for intergenerational learning and collaboration. Interactive booths, solar-powered games, and technology demonstrations, where students guide older participants, facilitate knowledge exchange and build trust.

Other effective strategies include partnering with established community groups such as Neighbourhood Watch, University of the Third Age (U3A), and other local organisations to promote inclusion, empowerment, and active participation among older adults. Neighbourhood Watch programs specifically encourage older adults to participate in community initiatives, fostering connections and reducing isolation (Neighbourhood Watch, 2020). These groups provide volunteering opportunities and social engagement, with an adaptable, grassroots model that welcomes members at varying levels of involvement. Similarly, U3A chapters offer educational, social, and volunteering opportunities designed for retirees and older adults (Retire On, 2025). U3A's collaborative structure actively encourages seniors to teach courses, participate in

decision-making, and shape local programming, enhancing their engagement and sense of purpose. Local councils and networks host a variety of clubs and groups that are well-suited for older members, including Men's Shed, Probus, Lions Clubs, Country Women's Association, and Older Women's Network (Older Persons Advocacy Network, 2025). Participation in these groups empowers older adults, enabling them to form meaningful relationships, share expertise, and stay socially and intellectually active (IRT, 2025). These events underscore the reciprocal nature of learning, demonstrating that every generation has valuable contributions to make.

Ultimately, intergenerational engagement fosters community resilience, leading to positive social outcomes and a deep understanding of the technology. This holistic approach not only educates the current generation but also lays the groundwork for future generations to champion sustainable energy solutions such as microgrids, making the transition to renewable energy more inclusive and enduring. Such engagement with children often creates a ripple effect as they share their knowledge and enthusiasm with their families, indirectly educating their parents and guardians about the advantages of microgrids. By embracing the strengths of each generation and fostering collaborative relationships, communities can create a more sustainable, equitable, and vibrant future for all.

## 7.5 Implications of including communities in the decision-making process

This discussion section examines the findings related to the research question: "Based on the research on Australian microgrids, what will be the implications of including local communities in the decision-making process on the energy policy involving microgrids and funding potential?" The research findings have revealed that the role of local communities in shaping microgrid projects is increasingly recognised as essential for ensuring the long-term success and sustainability of microgrids. Community involvement

not only influences the social acceptance and operational success of microgrids but also has policy and funding implications that can shape the broader energy transition in Australia. This section explores how greater community participation in the decision-making in microgrid projects impact the policy implications and future funding programs.

One of the most salient findings is that the level of community energy literacy plays a significant role in shaping engagement outcomes (see Chapter 5 section 5.2). Communities with higher levels of understanding about energy systems and microgrid technology demonstrated greater enthusiasm and proactive involvement in feasibility studies. In contrast, those with lower energy literacy levels faced significant barriers to meaningful participation. This disparity highlights the necessity for targeted educational initiatives that enhance public understanding of decentralised energy solutions and empower communities to take an active role in shaping their energy futures. However, the research has demonstrated that energy literacy varies significantly across communities, and project stakeholders cannot assume universal comprehension. Therefore, when designing community engagement strategies, it is essential to allocate resources for educational initiatives that empower citizens to actively participate in the decision-making process.

Furthermore, the research indicates that community energy groups, characterised by varying levels of energy literacy among members, may experience consultation fatigue, potentially leading to frustration. For instance, if the project team repeatedly explains the same concept to certain individuals, it can lead to consultation fatigue and subsequent frustration (see Chapter 4, section 4.3.3). This underscores the necessity of designing engagement processes that are transparent, outcome-oriented, and structured to minimise redundancy while maximising meaningful participation. Implementing clear milestones, demonstrating progress, and maintaining consistent communication are crucial strategies for sustaining community interest and trust.

The research has also highlighted several challenges that impact the microgrid project process, often leading to opposition or disengagement. One of the most frequently cited barriers is the lack of adequate funding for comprehensive community engagement. While feasibility studies typically receive government grants, the majority of this funding is allocated toward technical and economic assessments, leaving limited resources for meaningful community outreach and participatory activities. Several interviewees in this study emphasised that without sufficient funding, engagement efforts tend to be superficial, limiting opportunities for deep, collaborative decision-making processes that foster genuine community involvement and support.

To address this issue, funding policies for microgrid projects should mandate community engagement as a key deliverable, ensuring that allocated funds explicitly support activities aimed at community participation and capacity building. In addition, microgrid projects require long-term financial commitments, yet many communities struggle to secure sustained investment beyond the feasibility phase. A potential solution lies in exploring alternative financing mechanisms, such as community ownership models, power purchase agreements, and cooperative investment strategies. These approaches could enhance the financial viability and long-term sustainability of microgrid initiatives by ensuring that communities remain actively involved and benefit equitably from the projects they help shape.

### 7.5.1 Trends and Considerations in Microgrid Funding

An analysis of the rural and remote towns participating in the national RRCRF government-funded feasibility studies program revealed distinct trends. Two-thirds of the projects awarded funding were located in towns with populations between 500 and 10,000 people. This finding is noteworthy, as it contradicts the expectation that smaller communities, often considered ideal candidates for microgrid implementation due to their size and potential energy needs, would be more prevalent among the funded projects.

Smaller communities may face resource constraints that limit their ability to participate in competitive funding programs. Another prevalent characteristic that emerged from the research was the presence of seasonal tourism, with 60% of projects located in communities experiencing seasonal fluctuations in population and energy demand (see Chapter 5, Section 4.1). Despite this, only 11% of interviewees indicated that addressing seasonal power peaks was a primary expectation for microgrid implementation. Resilience and reliability emerged as stronger drivers for communities considering microgrid feasibility. Without detailed information regarding the project selection criteria for grant funding, it remains unclear whether these funded projects represent a truly representative sample of communities where microgrids are most desirable, viable, or feasible. Longitudinal monitoring of these projects beyond the funding period would provide valuable insights into their long-term outcomes. Such monitoring could track which communities ultimately implement full-scale microgrids, which adopt partial microgrid components (e.g., neighbourhood batteries or solar farms), and which do not progress with any local energy solutions. Analysing the factors contributing to these varied outcomes would enhance the understanding of microgrid feasibility and community adoption in diverse contexts.

### 7.5.2 Implications of less community participation in co-design and data interpretation processes

Research on community engagement in microgrid projects in Australia reveals a concerning trend: limited involvement of local community stakeholders in the co-design and data interpretation phases (see Chapter 5, sections 4.7 and 4.9). Community input is often overlooked in these stages, as the technical results of feasibility studies may not be fully shared with the community. This exclusion stems from various factors, including concerns that findings may not align with community expectations and fear of potential opposition. Additionally, communities in remote areas, possess limited energy literacy,

making it challenging to interpret the technical aspects of microgrid projects. While developers may perceive this as a hurdle to collaboration, it underscores the need for tailored communication strategies that simplify complex information and make data more accessible. Without such efforts, community members may feel alienated from the decision-making process, potentially leading to project opposition and mistrust towards the project stakeholders.

Excluding community members from these discussions can diminish trust, leading to misunderstandings and resistance and, ultimately, undermining long-term project success. This opposition can hinder future funding opportunities for community engagement activities, as the lack of comprehensive and effective engagement may be perceived as a failure to meet necessary project requirements. Furthermore, neglecting to include communities in the decision-making process inadvertently creates a power imbalance, giving the perception that external stakeholders dominate project outcomes while local voices are marginalised. Addressing these challenges requires a commitment to inclusive and transparent engagement. Developers must proactively address community concerns, align project objectives with local priorities, and maintain clear and open communication throughout the project lifecycle. Investing in participatory approaches that prioritise co-design and data sharing is crucial for fostering community ownership and ensuring equitable and sustainable outcomes. By empowering communities with knowledge and actively involving them in decision-making processes, microgrid projects can truly serve as catalysts for sustainable development and self-determination.

### 7.5.3 Key Lessons for Community Engagement

Drawing from the research findings presented in Chapters 5 and 6, this section delineates key lessons pertaining to community engagement that have emerged from this thesis.

#### 7.5.3.1 Need for Early Engagement

Early initiation of community consultations is crucial within the project lifecycle. Rather than presenting communities with predetermined plans, developers and policymakers should prioritise stakeholder engagement from the outset. This proactive approach involves hosting preliminary meetings, workshops, and forums where stakeholders can express their aspirations, concerns, and cultural values before finalising critical design or funding decisions.

#### 7.5.3.2 Culturally Appropriate Communication

Effective community engagement necessitates adapting to the community's cultural context. Technical jargon, complex legal terminology, and unfamiliar policy frameworks can alienate community members. Therefore, clear and accessible communication strategies are essential. This includes translating technical details into accessible language, incorporating visual aids, and utilising interpreters and local mediators to ensure all participants feel equipped to engage. This two-way exchange fosters trust and ensures community understanding of the project's technical, economic, cultural, and environmental dimensions.

#### 7.5.3.3 Recognition of Local Leadership

Decision-making processes vary across communities, necessitating an understanding and integration of existing leadership structures. These structures may encompass traditional governance patterns or contemporary local bodies. Incorporating these systems into the project's governance framework, potentially through advisory committees or joint management arrangements, ensures that decision-making processes reflect local voices and garner long-term community support.

#### 7.5.3.4 Financial Support and Capacity Building

Effective participation in complex energy projects often necessitates that communities receive financial and technical support. Offering grants, seed funding, training, and

educational programs empowers community members to become active partners, fostering local ownership and increasing the likelihood of long-term microgrid sustainability.

#### 7.5.3.5 Transparency

Open communication and access to information are vital. Making budgets, timelines, and decision criteria publicly accessible enables community members to hold project leaders accountable, reducing scepticism and mitigating potential conflicts. Transparency builds trust and ensures continued community engagement throughout the project lifecycle, from initiation to operation, maintenance, and future expansion.

By embracing these lessons, communities across Australia can foster more inclusive and participatory energy development processes, leading to projects that genuinely reflect local needs and priorities while ensuring equitable and sustainable outcomes.

#### 7.5.4 Concluding remarks

Reflecting on research question 3, the findings have demonstrated that the inclusion of local communities in the decision-making process leads to more successful microgrid project outcomes. Meaningful participation fosters social acceptance, enhances trust, and ensures that project outcomes align with community needs and expectations. When communities are actively involved, there is a greater likelihood of long-term project sustainability as local stakeholders develop a sense of ownership and commitment to the initiative.

However, the research findings indicate that some community engagement strategies in microgrid projects follow a top-down approach, where decisions are made by external stakeholders with limited input from the local community. This exclusionary approach can lead to project opposition, disengagement, and mistrust, ultimately jeopardising project implementation and long-term viability. Failure to integrate communities into the decision-making process can have far-reaching consequences, including delays in project

progress, misalignment with policy goals, and potential funding challenges. If community engagement is perceived as inadequate or ineffective, it can hinder future funding opportunities, as policymakers and funding bodies may view such projects as lacking local support or failing to meet community needs. Recognising the critical role of community engagement, many funding guidelines, including those under the Regional and Remote Communities Reliability Fund (RRCRF), emphasise the importance of community capacity-building. However, while funding frameworks acknowledge the need for engagement, they often lack specific directives on the depth and extent of community participation required, leaving project stakeholders without clear guidance on how to structure their engagement strategies effectively.

To enhance the effectiveness of future funding programs, it is crucial that funding guidelines clearly define the level of community engagement expected. This will allow project developers and policymakers to design comprehensive, context-specific engagement strategies that ensure community perspectives are not only considered but actively integrated into decision-making processes. Establishing more explicit engagement benchmarks within funding criteria can improve the overall social, technical, and financial feasibility of microgrid projects, strengthening their role in Australia's broader energy transition.

## 7.6 Social acceptance around microgrids

This discussion section examines the findings related to the research question: "Based on the research on Australian microgrids, what will be the implications of including local communities in the decision-making process on the energy policy involving microgrids and funding potential?" The role of local communities in shaping microgrid projects is increasingly recognised as essential for ensuring the long-term success and sustainability of these initiatives. Community involvement not only influences the social acceptance and operational success of microgrids but also has policy and funding

implications that can shape the broader energy transition in Australia. This section explores whether community engagement strategies in the microgrids support social cohesion or create conflicts.

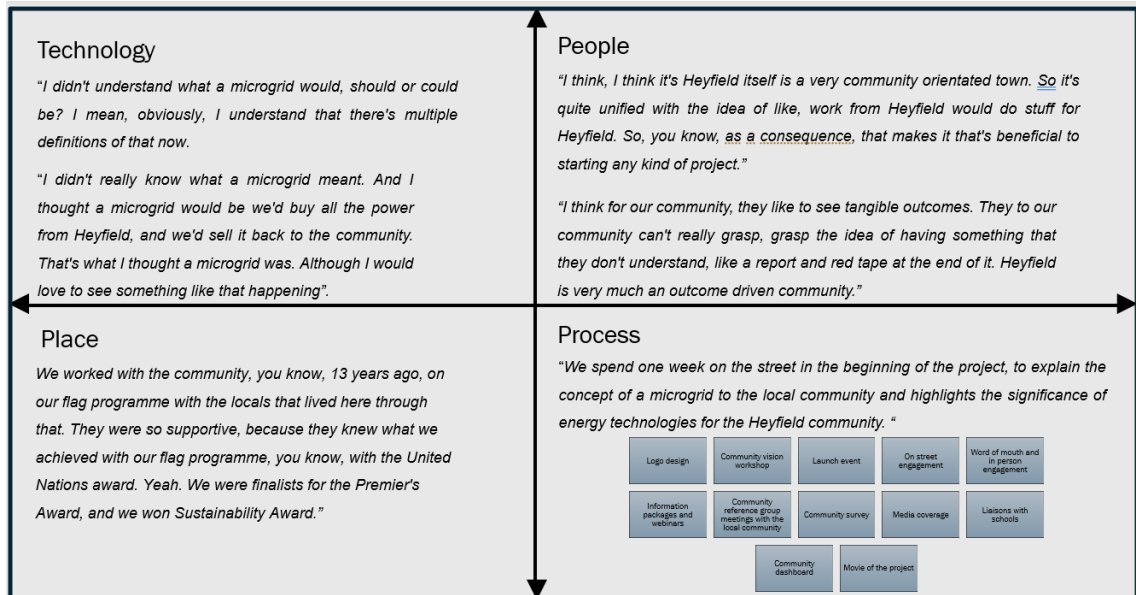


Figure 44 Community perceptions on Technology, People, Place and Process

As demonstrated in Chapters 5 and 6, social acceptance is crucial for the successful implementation of microgrid projects. However, achieving this acceptance is a complex process, and the Technology, People, Place and Process framework provides an effective tool to understand the perceptions.

A comprehensive analysis of the Heyfield case study illustrates that technology, people, place, and process impact the project's perceptions. The community engagement strategies needed to be designed in alignment with these factors. Figure 44 shows how the communities perceive microgrid technology and how the project team develops engagement strategies to promote community acceptance.

Past experiences with external developers, energy projects, or government initiatives significantly influence a community's initial perceptions of new projects. Communities with a history of positive collaboration may exhibit greater receptivity towards new

initiatives, while those with experiences of exploitation or marginalisation may approach new projects with scepticism. This emphasises the need for engagement strategies that are not only participatory but also reflective of the community's unique cultural and social dynamics. Significantly, the research findings (see Chapter 6, section 6.4) reveal that the community engagement process is not static; it must evolve alongside the dynamic interplay between the project and the community. Successful community engagement needs to incorporate a fast approach based on flexibility and adaptability, as the factors influencing acceptance are rarely constant. Therefore, engagement strategies should be continuously reassessed and adjusted to maintain their relevance and effectiveness.

In conclusion, effective community engagement in microgrid projects necessitates a holistic understanding of the social, cultural, and contextual factors that influence acceptance. It is not a one-size-fits-all process, but rather an evolving practice that must adapt to each community's unique characteristics and changing dynamics. By acknowledging and addressing these complexities, project teams can foster trust, improve social acceptance, and ensure the long-term success and sustainability of microgrid initiatives.

### 7.6.1 Community engagement – creating cohesion or conflicts

A key finding of this study is that while communities demonstrate strong interest and motivation to engage with microgrid projects, the inherent complexities associated with these projects, such as technical aspects, regulatory frameworks, and financing models, present significant challenges for community comprehension and participation (see Chapter 5, section 4.3). Many community members expressed enthusiasm for the transition to localised renewable energy solutions, recognising the potential benefits of microgrids in terms of energy independence, sustainability, and resilience. However, as engagement progresses, the intricacies of technical, regulatory, and financial considerations often lead to frustration, disengagement, and even dropouts from the

process. This disengagement suggests that existing community engagement strategies may not always be effective in maintaining long-term participation and ensuring social cohesion.

This challenge underscores the importance of expectation management at the very beginning of community engagement processes. Professionals and project facilitators must acknowledge that while enthusiasm for microgrids is high, communities require clear, realistic, and accessible information about what can be achieved, the timeline of implementation, and the roles they are expected to play. Without early and transparent communication, unrealistic expectations may develop, leading to disappointment, resistance, and even opposition (see Chapter 6, section 6.2). Therefore, engagement strategies must be adaptive, ensuring that communication approaches are tailored to different levels of technical understanding while also addressing social and emotional concerns that arise throughout the process.

A crucial aspect of effective engagement is ensuring that the community is not merely a passive recipient of information but rather an active participant in decision-making. Traditional top-down approaches, where information is "spoon-fed" to the community without meaningful dialogue, can lead to distrust and disengagement. Instead, microgrid projects must foster capacity-building initiatives that equip community members with the knowledge and skills to critically engage with energy transition discussions and contribute to project decisions. This requires co-designed engagement models, where community members are not only informed but also empowered to shape the direction of the microgrid project.

Furthermore, the social acceptance of microgrids depends heavily on how inclusivity and transparency are embedded into engagement strategies. If engagement efforts fail to address concerns of equity such as fair distribution of benefits, affordability, and governance structures, social tensions may emerge, leading to divisions within the community rather than cohesion. In contrast, when communities feel that their voices are

heard, their concerns are validated, and their participation is meaningful, microgrid initiatives are more likely to foster collective ownership and long-term acceptance.

In conclusion, while community engagement strategies play a vital role in building social cohesion around microgrid projects, they must be carefully designed to navigate the complexity of expectations, technical challenges, and social dynamics. Ensuring that communities have both the capacity and agency to engage meaningfully while also managing expectations and providing clear communication is essential for minimising frustration and dropout rates. Ultimately, microgrid acceptance hinges not just on technological and economic feasibility but also on the ability to create trust-based, inclusive, and participatory engagement processes that foster a sense of collective ownership and long-term commitment to the energy transition.

### 7.6.2 Concluding remarks

Reflecting on research question 4, the findings suggest that effective community engagement plays a crucial role in fostering social acceptance of microgrid projects; however, if engagement is poorly managed, it can lead to conflict, mistrust, and disengagement within the community. One of the key challenges is that there is no universal "best practice" for community engagement, as each community has its own distinct social dynamics, priorities, and concerns. What works in one setting may not necessarily be effective in another, requiring tailored engagement strategies that address the specific needs and expectations of different communities. Therefore, successful community engagement must be flexible, context-specific, and built on continuous dialogue, ensuring that local stakeholders are meaningfully included in the decision-making process to enhance long-term project success.

To conclude, this discussion chapter provides a comprehensive analysis of the findings from the research conducted as part of this thesis, offering insights from academic publications. The chapter successfully demonstrated how the research questions have

been answered by employing the correct methodologies and having a comprehensive discussion of the research findings.

## 7.7 References

ABS. (2024). *Life expectancy 1993 to 2021-2023*.

Australian Bureau of Statistics. (2021). *Estimates of Aboriginal and Torres Strait Islander Australians*.

Barbara Misztal. (1996). *Trust in Modern Societies: The Search for the Bases of Social Order*.  
<https://www.wiley.com/en-au/Trust+in+Modern+Societies%3A+The+Search+for+the+Bases+of+Social+Order-p-9780745616346>

Buffel, T., De Backer, F., Peeters, J., Phillipson, C., Reina, V. R., Kindekens, A., De Donder, L., & Lombaerts, K. (2014). Promoting Sustainable Communities through Intergenerational Practice. *Procedia - Social and Behavioral Sciences*, 116, 1785–1791.  
<https://doi.org/10.1016/j.sbspro.2014.01.472>

Crespo, J. R., & du Preez, J. (2014). Promoting community engagement in an intergenerational program: an exploratory study. *Australian Community Psychologist*, 26(1), 67–76.

Department of Climate Change, Energy, the Environment, and W. (2022). *Regional and Remote Communities Reliability Fund*. <https://www.energy.gov.au/government-priorities/energy-programs/regional-and-remote-communities-reliability-fund>

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. In *Research Policy* (Vol. 31).

- Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). The Socio-Technical Dynamics of Low-Carbon Transitions. *Joule*, 1(3), 463–479. <https://doi.org/https://doi.org/10.1016/j.joule.2017.09.018>
- Hatton-Yeo, A. (2010). An introduction to intergenerational practice. In *Working with Older People* (Vol. 14, Issue 2, pp. 4–11). <https://doi.org/10.5042/wwop.2010.0261>
- IRT. (2025, June 15). *10 ways to empower older adults*. <https://www.irt.org.au/the-good-life/ways-to-empower-older-adults/>
- Koirala, B. P., Araghi, Y., Kroesen, M., Ghorbani, A., Hakvoort, R. A., & Herder, P. M. (2018). Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems. *Energy Research and Social Science*, 38(December 2016), 33–40. <https://doi.org/10.1016/j.erss.2018.01.009>
- Lawrence-Jacobson, A. R. (2006). Intergenerational community action and youth empowerment. *Journal of Intergenerational Relationships*, 4(1), 137–147. [https://doi.org/10.1300/J194v04n01\\_15](https://doi.org/10.1300/J194v04n01_15)
- Luhmann, N. (1979). *Trust and Power*.
- National Seniors Australia. (2024). *Harnessing the wisdom within*.
- Neighbourhood Watch. (2020). *Strategic Plan 2020-2025*. <https://www.ourwatch.org.uk/sites/default/files/documents/2020-12/Strategic%20Plan%202020-25%20Final.pdf>
- Older Persons Advocacy Network. (2025). *Community connection*. <https://opan.org.au/get-support/community-connection/>
- Play matters. (2024). *The Benefits of Intergenerational Play: Bridging Generations Through Fun and Learning*.

Retire On. (2025). *Exploring the University of the Third Age: A Guide*.  
<https://retireon.com.au/university-of-the-third-age>

Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663. <https://doi.org/10.1016/j.enpol.2009.05.055>

# Chapter 8:

# Conclusions



Microgrids in Bushfire-prone Australian communities. Retrieved from Microgrid Knowledge <https://www.microgridknowledge.com/community-microgrids/article/33009609/new-community-microgrid-brings-resilience-to-nsw-coastal-communities>

## Chapter 8. Conclusions

### 8.1 Introduction

This thesis originated against a backdrop of growing concerns over climate change, increasingly frequent and severe extreme weather events, a global energy transition away from fossil fuels, and gaining community momentum on renewable energy. Microgrids that integrate renewables and energy storage have been proposed as largely a technical solution for addressing these challenges for rural and remote communities. However, the literature review presented in Chapter 2 revealed a significant gap in understanding the social dimensions of microgrids despite extensive research on their technical and economic aspects. This gap pertains particularly to the role of community engagement and social acceptance in facilitating the wider adoption of microgrids, which constituted the primary aim of this thesis. Therefore, this thesis aimed to gain a comprehensive understanding of the role of microgrids in the Australian energy transition, with a particular focus on the social dimensions and the factors that may help support the transition of microgrids from their current niche applications toward broader adoption within the mainstream energy system. Before concluding the thesis, this chapter will highlight the key understandings that emerge from the thesis, its contribution to scholarship, and the research outcomes in relation to the research objectives and questions. The chapter will conclude by identifying the research limitations and the future course of study.

### 8.2 My contribution to the knowledge

This thesis makes a new contribution to the academic literature by addressing critical gaps in the study of the social dimensions of microgrids within an Australian context. Foremost among these contributions is the publication of two peer-reviewed academic papers and the submission of a third manuscript to international journals. These

publications augment the existing body of knowledge by examining the role of social dimensions in microgrid adoption in Australia. Specifically, this research focusses on:

- Developing a nuanced understanding of the barriers and opportunities associated with the acceptance of microgrids in different community contexts, including remote, rural, and First Nations communities.
- Providing a deeper understanding of how community engagement approaches are applied by practitioners, drawing on real-world Australian microgrid feasibility projects.
- Exploring the potential misconceptions surrounding the notion of "good practice" in community engagement, highlighting the limitations of standardised approaches that may not adequately address the complexities and unique dynamics inherent in specific communities.
- Understanding whether the necessary engagement needed for a community to make an informed decisions on a microgrid's feasibility supports social cohesion or instead leads to conflicts.

By examining these critical aspects, this thesis advances the discourse on microgrids in Australia, contributing to a more comprehensive understanding of the socio-technical challenges while providing valuable knowledge which informs policy development, improve community engagement practices, and ultimately supports the transition towards a more sustainable and equitable energy future.

Beyond the immediate focus on microgrids, this research also highlights new avenues for further study. One such area is the concept of intergenerational community engagement, which emerged in some of the case studies examined in this thesis (see Chapter 7, section 7.12). This approach, which involves engaging multiple generations within a community to foster long-term support for renewable energy initiatives, warrants further exploration. Additionally, the principles of community engagement discussed in

this thesis could be extended to other emerging energy technologies, broadening the impact of this research beyond microgrids alone. Questions relating to social equity of microgrids could also be explored further, particularly of those communities who are already supplied power by them and what their experiences tell us about how we should design microgrids around communities in future. A longitudinal study of the microgrid projects featured in this research would help understanding of the effectiveness of funding programs for feasibility studies such as this, which could explore spillover effects (such as jobs creation and skills development) as well as whether a microgrid was implemented or not. An international comparison of this experience with other countries where microgrid deployment is also increasing could also help uncover new insights for the design or policy and programs for microgrids or other complex community energy infrastructure. By shedding light on these unexplored areas, this thesis lays the groundwork for future interdisciplinary studies on the intersection of technology and community engagement within the energy sector.

### 8.3 Research outcomes against research questions

This thesis has successfully addressed all the research questions, for which detailed responses are presented in Chapter 7. Figure 45 maps the alignment between the research objectives, research questions, and the methodologies employed, demonstrating how the research objectives and research questions have been answered.

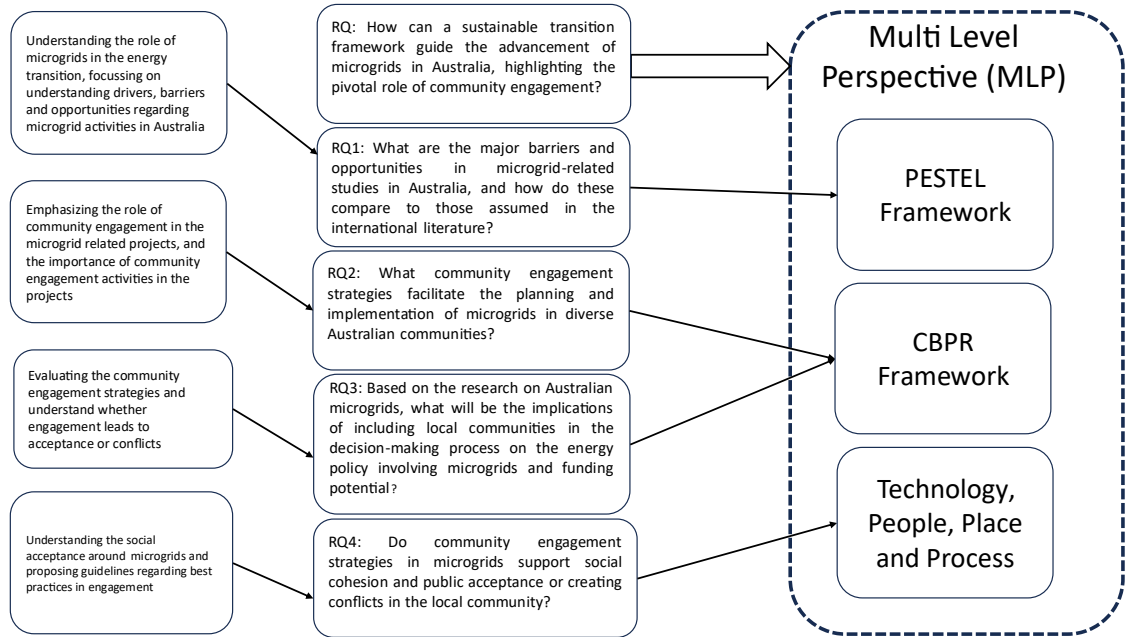


Figure 45 Mapping of Research Objectives with Research Questions and Adopted Methodology

## 8.4 Limitations of the research

This research, while contributing valuable insights, has limitations as well that warrant acknowledgement. First, the thesis relied primarily on the findings from the projects funded under the Regional and Remote Communities Reliability Fund (RRCRF), limiting the scope to initiatives supported by a single funding program. This focus excludes projects funded by other schemes, such as those initiated by the Australian Renewable Energy Agency (ARENA) or private stakeholders, which might have resulted in additional perspectives or contrasting findings.

The feasibility status of many microgrid projects included in the study remains unknown, as the research was conducted before the completion of these studies. Consequently, it is unclear whether the microgrids under consideration were ultimately considered a viable option, creating a gap in understanding the full trajectory from feasibility to implementation.

From the 36 projects funded under the RRCRF program, 22 interviews were conducted. While this covered around 86% of the communities for which feasibility studies were undertaken, it still represents a gap in understanding the perceptions of microgrids for those remaining 14% of communities.

Another limitation lies in the number of case study analysis being conducted as part of the research. While one in-depth case study provided a detailed and granular understanding of microgrid dynamics, community engagement strategies and the emerging conflicts in the community, conducting more in-depth case study analysis might have resulted in a more diverse and potentially dynamic dataset. However, the lack of availability of the project stakeholders and the resources to conduct deeper case study analysis were the reasons behind a single, albeit in-depth, case study analysis.

The research also highlights the need for further exploration of the implementation phase of microgrid projects. While this study focuses primarily on feasibility, bridging the gap between feasibility and implementation is critical for translating potential into tangible outcomes. This requires not only additional research but also sustained funding mechanisms to support the transition. Moreover, the social dimensions of microgrids are a complex domain that extends beyond the scope of this research. Key concepts related to social research, such as social justice, social license, and the role of local governments and councils in microgrid projects, remain underexplored and need further research moving forward.

While this research provides valuable contributions, the limitations outlined point to opportunities for future studies. Addressing these gaps further enriches the field of microgrid development and deployment, and understanding the social dimensions will help transition this from niche innovations to existing regimes.

## 8.5 Future research

Several promising avenues for future research remain open. Further investigations could explore comparative case studies across diverse rural and remote communities to assess how varying social, economic, and geographical factors influence microgrid adoption. Understanding these differences will further facilitate the identification of scalable engagement frameworks adaptable to diverse community contexts.

Further research could investigate the transition of RRCRF-funded feasibility studies into implemented microgrid projects, including an examination of which projects subsequently received implementation funding through programs such as the Australian Renewable Energy Agency (ARENA). This would allow for an assessment of the proportion of studies that successfully progressed to deployment compared to those deemed unfeasible. A comparative analysis of successful and unsuccessful feasibility studies could help identify the critical factors influencing these outcomes. Additionally, analysing projects supported through different funding sources—such as RRCRF, ARENA, private investment, or community-driven initiatives—could provide valuable insights into how various funding mechanisms shape microgrid development, implementation, and long-term success.

Longitudinal studies examining community energy transitions represent another key area for future research. Tracking community perceptions and participation over extended periods will provide deeper insights into the evolution of engagement strategies and their long-term impacts on microgrid feasibility and implementation. Additionally, further research could investigate the economic and financial models that best support community-led microgrid initiatives, including cooperative ownership models and public-private partnerships.

Future studies should also delve into the role of digital platforms and smart technologies in facilitating community engagement and optimising microgrid operations. With the rise

of AI-driven energy management solutions, research can explore how these innovations influence community participation and trust in decentralised energy systems.

Finally, interdisciplinary research that bridges social science, engineering, and policy studies will be critical in addressing the regulatory, financial, and social barriers to microgrid deployment. Future investigations should focus on how policy frameworks can better support community-driven energy transitions, ensuring that local needs and aspirations are embedded in national energy strategies.

## 8.6 Concluding thoughts

In conclusion, the research has demonstrated that the success of an inclusive energy transition relies not only on technological advancements but also on community participation and involvement. This can often be overlooked, as the existing academic literature has shown. Effective engagement with local communities strengthens social networks, enhances awareness of renewable energy opportunities, and facilitates knowledge-sharing. This can ultimately lead to more inclusive and informed decision-making. This thesis has addressed a critical gap in the academic literature by examining the social dimensions of microgrids for rural and remote communities in Australia, a crucial aspect for transitioning these technologies from niche applications to widespread integration within the dominant energy regime. Through a comprehensive literature review, this research identified significant gaps in understanding community engagement and social acceptance in this context. To bridge these gaps, a robust social research design was established that incorporated philosophical considerations, theoretical frameworks, and methodological underpinnings.

Employing a qualitative approach, this study enabled an in-depth exploration of stakeholder perceptions, community engagement practices, and socio-technical challenges associated with microgrid implementation. Chapter 4, comprising the first publication, analysed microgrid drivers, barriers, and opportunities in Australia, providing

a comprehensive overview of the current landscape based on real projects. Chapter 5, comprising the second publication, investigated how community engagement practice was being applied with those same projects, identifying key strategies, challenges, and complexities.

By acknowledging the nuanced nature of community engagement in complex energy projects, this research contributes valuable knowledge and offers practical guidance for future microgrid initiatives. Chapter 6, comprising a submitted article, provides further analysis of the factors influencing social acceptance of microgrids based on a case study of a rural town, examining whether community engagement strategies foster cohesion or conflict. Chapter 7 synthesised the research findings, elaborating on emergent themes and demonstrating how the thesis has addressed all research questions.

This thesis offers valuable insights for community engagement practitioners, community leaders, policymakers, project developers, and energy utilities who must navigate the social complexities of microgrid adoption and facilitate a just and equitable energy transition. By promoting a deeper understanding of community engagement, social acceptance, and the interplay of socio-technical factors, this research contributes to the growing body of knowledge on microgrids and other complex community energy solutions and their potential to transform energy systems in Australia and beyond.

The research findings presented in this thesis offer lessons that extend beyond the Australian context for other regions exploring microgrids as a solution for sustainable energy transitions. Specifically, this research can inform policy and program development for microgrid initiatives, as well as other complex community energy projects, in several ways:

- **Community Engagement:** The findings underscore the critical importance of inclusive community engagement strategies. By understanding the diverse needs, values, and aspirations of communities, project developers and

policymakers can foster trust, build partnerships, and ensure that energy projects align with local priorities.

- **Social Acceptance:** This research highlights the complex interplay of factors influencing social acceptance of microgrids, including technology, people, place and processes. These insights inform the design of engagement strategies that address community concerns and promote wider acceptance of energy projects.
- **Capacity Building:** The thesis emphasises the need for capacity-building initiatives that empower communities to actively participate in energy decision-making. By providing knowledge sharing platforms, access to information, training, and resources, policymakers can foster local ownership and ensure that microgrid projects are equitable and sustainable.
- **Policy Frameworks and Programs:** The findings offer valuable insights for policymakers seeking to develop supportive regulatory frameworks and policy programs for microgrids. By understanding the barriers and opportunities associated with their adoption, policymakers can create enabling environments that encourage innovation, investment, social benefit, and community participation in decentralised energy systems.

In conclusion, this research offers a framework to improve understanding of the social dimensions of microgrid adoption while providing practical guidance for those seeking to implement community-centric energy solutions. The findings have implications beyond the Australian context, contributing to a global understanding of how to effectively navigate the social complexities of energy transitions and ensure that they are just, equitable, and sustainable for all communities. This research has also illuminated pathways for microgrids to transition from niche innovations to broader adoption within the existing regime, ultimately playing a vital role in the energy transition of rural and remote communities.

## Bibliography

The list of Bibliography has been presented with every chapter separately for the ease of the readers.

## Appendix

### Interview guide for the RRCRF interviews

#### **Introduction:**

**Please explain the RRCRF/Microgrid related project you're involved in and your role in it?" (Introduction of the project) 10 mins**

- What are the major drivers for the proposition of microgrid in the region?
  - How does the idea emerge?
  - Why is the community motivated towards the microgrid?
- Since there are multiple definitions of microgrids, how will you define a microgrid and its features?
- What is the proportion of people with rooftop solar or other renewable energy resources?
- What is the major source of DER in the region?
- What is the level of awareness of the local community towards climate change and the integration of DERs in the system?
- What are the other alternatives (other than the microgrids) that the team has worked on i.e., any other technology?
- What energy monitoring devices are employed in the region, and how was the data collection process?
- Were any other local energy solutions being considered (e.g., VPPs or community batteries)

#### **Microgrid boundary:**

- What are the perceptions about the microgrid boundary? How did the team manage to set a boundary for the project?

#### **Islanding:**

- What are the results regarding the islanding feature of the microgrid?
  - Technical feasibility, community response towards islanding

**Techno-economic feasibility:**

- How did the team do the techno-economic analysis (software and tools used)

**Community dynamics:**

- What are the community dynamics regarding a social relationship, i.e., closely knitted community or diverse? Also, can you tell a little bit about the demographics, in terms of middle-aged people, international people, native, aboriginal people, blue-collar or white collar etc., their level of education and skillset?

**Community participation in the decision-making process:**

- What did the community turnout or participation rate in organized events such as workshops or webinars for the project?
- How has community engagement shaped the decision-making process? OR give an example where community engagement changed the project's direction.
  - How do behaviours and attitudes of the local community shape the project's progress or outcome? Or how the decisions/inputs from the community have driven the project. (Perceive according to the responses)
- How did community engagement differ in COVID times, and what challenges did the community engagement team face?

**Community engagement strategies:**

- What is the role of the community in the microgrid feasibility study, and what are the measures taken to involve the community in the project? (Active participation or not)
- What is the most significant community engagement strategy employed?

- For the community engagement, are there any recommendations that would've given better results?

**Community drivers and motivation:**

- What are the major drivers/motivating factors for the communities towards the project?
- Has there been any increased awareness and understanding of the feasibility and benefits of microgrid systems and technologies to date in contrast to the start?
- How do we continue the level of community engagement throughout the end of the project?

**Role of community energy groups:**

- For the project where community energy groups are involved: how the community energy groups are dealing with the complexity of microgrids in terms of expertise, resources, and technical advancements

**Barriers and opportunities in the project:**

- What are the barriers and opportunities encountered in the feasibility study, and how did the team strategize to resolve these issues and barriers?
  - Technical barriers/opportunities
  - Social and regulatory barriers/opportunities
  - Probe major challenges and steps taken to encounter those.

**Regulatory work:**

- What is the role of the local government or local council in the project?

**Conclusion:**

- What is the likelihood that the feasibility study will be a microgrid? If finished, what was the outcome of the project?

- Do you have any recommendations to enhance future funding and microgrid activity in Australia to make microgrids a mainstream sustainable energy solution?

## Resources for Heyfield MyTown Microgrid Project

<https://www.heyfieldcommunity.org.au/mytown-microgrid>

<https://www.gippslandtimes.com.au/community/2021/03/01/heyfield-community-embraces-innovative-microgrid-project/>

<https://www.gippslandtimes.com.au/news/2023/06/07/marking-end-of-the-mytown-microgrid-project/>

[https://www.heyfieldcommunity.org.au/files/ugd/2ec4c2\\_646c4c4139354b6680f3e38f21049218.pdf](https://www.heyfieldcommunity.org.au/files/ugd/2ec4c2_646c4c4139354b6680f3e38f21049218.pdf)

## Microgrid projects from the round 1 funding of RRCRF

<b>Microgrid project</b>	<b>State</b>	<b>Funding Recipient</b>	<b>Funding</b>
Cowra Microgrid Detailed Feasibility Study (good data given)	NSW	C.L.E.A.N. (Cowra) Incorporated	\$1,031,556
Developing Commercial microgrid models for regional C&I businesses	Queensland	Yurika Pty Ltd	\$968447
Mutitjulu & Martu Community Microgrid Project: Feasibility Study	Northern Territories	Impact Investment Partners Pty Ltd	\$519954
Donald and Tarnagulla Microgrid Feasibility Study (good data given)	Victoria	Centre for New Energy Technologies Ltd.	\$1404750
Exmouth Microgrid- 100% Renewable Energy Town Transition	Western Australia	Regional Power Corporation WA	\$600000
Santa Teresa Microgrid Project	Northern Territory	Atyehenge-Atherre Aboriginal Corporation	\$303371
Effective, responsible energy solutions for remote indigenous communities	Western Australia	Alinga Energy Consulting Pty Ltd	\$473670
Alice Springs Future Grid Project	Northern Territory	Desert Knowledge Australia	\$3,197,507
Yarrabah Microgrid	QLD	Ener-G Management Group Pty Ltd	\$1976451
Power Smart Farm Electricity Generation	NSW	Innovating Energy Pty Ltd	\$3000000
Indian Ocean Territories Renewable Energy Microgrid Feasibility Study	WA	Island Power Co Pty Ltd	\$315504
NT Microgrid Futures Project (SETuP 2.0) (good info about Setup 1.0 there)	NT	Power And Water Corporation	\$1210000
The flow on benefits of microgrids for irrigated agriculture	QLD and NSW	Queensland Farmers' Federation Ltd	\$654807
Energy for all: Modernising microgrids for Aboriginal Western Australians	WA	Regional Power Corporation	\$1402128
Yackandandah Islandable Microgrid Project (good info is available)	Victoria	Totally Renewable Yackandandah Inc.	\$346644
MyTown Microgrid: a community and data-driven feasibility	Victoria	WattWatcher Pty Ltd and UTS	\$1787300

## Microgrid projects from the round 2 funding of RRCRF

<b>Microgrid project</b>	<b>State</b>	<b>Funding Recipient</b>	<b>Funding</b>
Clair view Beach and Stanage Bay Community Microgrid Feasibility Study	QLD	Ergon Energy Corporation Ltd	\$907281
Fringe-of-Grid Futures South Australia Eyre Peninsula	SA	IT Power (Australia) Pty Ltd	\$1080945
Hydrogen Hubs powering remote communities (H2H)	QLD	Ergon Energy Corporation Ltd	\$546720
Coolgardie Microgrid Feasibility Assessment	WA	Resources WA Pty Ltd	\$1204100
Northern Territory microgrids– sustainable and resilient remote communities	NT	Power Generation Corporation	\$2884588
Cobargo Microgrid Feasibility Study and Load Control Trial	NSW	ITP Development Pty Ltd	\$1363355
Transitioning Mid-West towns to 100% renewable energy	WA	Regional Power Corporation	\$650000
Mullewa Microgrid Feasibility Study Project	WA	Sunrise Energy Group Pty Ltd	\$1377101
Active Energy Precincts: Building stronger regional communities	VIC	Monash University	\$1934337
Sustainable Microgrid at Arkaroola and Outback Energy Technology Showcase	SA	Apex Energy Australia Pty Ltd	\$1365628
Transferrable Benefits from Feasibility Study of Derwent Bridge Microgrid	TAS	Tasmanian Networks Pty Ltd	\$1601143
Upper Murray Islandable Microgrid Project	VIC	Indigo Power Ltd	\$615660
Wujal Wujal Community Microgrid	QLD	Volt Advisory Group Pty Ltd	\$1995000
Borroloola Township and Outstations Microgrid Project: Feasibility Study	NT	Original Power Ltd	\$832400
Feasibility of Renewable Hydrogen to decarbonise the Esperance Region in WA	WA	Regional Power Corporation	\$700000
Bawley Point Kiola Resilient Energy project	NSW	Endeavour Energy Network Pty Ltd	\$865000
Southcoast u-grids Reliability Feasibility (Surf) project	NSW	Australian National University	\$3125913
Napranum & Muralug Microgrids Feasibility Study	QLD	Ener-G Management Group Pty Ltd	\$1732940
Aggregated Community-scale Battery Storage in Northeast Victoria	Vic	Indigo Power Ltd	\$539786
Providing reliable energy solutions to WA Indigenous outstations	WA	Generators & Off Grid Energy Pty Ltd	\$286074