Microgrids for resilience?

Findings from the SμRF project

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Battery Storage and Grid Integration Program
An initiative of The Australian National University

SμRF

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A partnership between

Australian National University

essential energy

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Executive summary

The Southcoast µ-grid Reliability Feasibility (SµRF) project investigated the possibilities for grid-tied microgrids in the Eurobodalla south coast of NSW, as well as the broader context of energy resilience in Australia.

This, the final report from SµRF, summarises the project's findings. It describes how resilience differs from reliability, and how these differences demand more wholistic approaches both intellectually and functionally across policy frameworks and institutional arrangements. It highlights the salient features of grid-tied microgrids: what they are, how they can and cannot contribute to resilience, and how they align and diverge from community expectations.

The endpoint of the analysis is that resilience, and vulnerability, are highly dependent on socio-economic arrangements and infrastructures, as well as physical infrastructures. Microgrids can therefore at best address one component of resilience, while simultaneously being shaped by socio-economic circumstances and goals.

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At present, there are significant gaps between the capabilities and costs of grid-tied microgrids and the expectations and desires of communities. Contributing factors of which include the prohibitive cost of batteries that can store the amount of energy required for extended power supply after major events; the inability to monetise resilience improvements as well as other network services that microgrids could offer, and; the equity implications of localised energy systems that include some community members and exclude others.

Ultimately, energy resilience and decarbonisation are systemic transitions that require engagement and actions from a great many actors, from individuals to national institutions. The issues of how these transitions are governed – who is involved, how they collaborate, how decisions are made and popularised – have stood out as the most pertinent of all issues covered in SμRF. While responsibility for this governance is distributed across many – and we make some specific suggestions – responsibility for leading and coordinating these processes ultimately rests with the federal government and national institutions.

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Image: Eurobodalla Coast Tourism ©

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Introduction

The Australian electricity system is undergoing an unprecedented transformation in response to the urgent need to reduce greenhouse gas emissions and the availability of new energy technologies. Simultaneously, the effects of an already substantially heated world are being felt by people and ecosystems across the country, as well as by the electricity system.

In the Eurobodalla, where the Southcoast µ-grid Reliability Feasibility (SµRF) project was focused, the impacts of climate change were felt profoundly in the extensive bushfires and the subsequent major flooding events of 2019–21.

These types of extreme events underscore the importance of enhancing the resilience of communities and the energy systems that support them.

These interrelated imperatives – of mitigating climate change, by rapidly reducing emissions, and adapting to climate change, through more resilient systems – are therefore two prominent goals for the energy transition.

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While these goals are clear and uncontroversial, the questions around how they should be pursued are complex and contested. These questions are also of significance for the design choices we make, which will ultimately determine what future energy system society creates.

It is within this context of possibilities, uncertainty and transition that grid-tied microgrids are being considered as a potential feature of future electricity systems. In this, microgrids must be seen as only one of many other options for pursuing the transition goals, including emerging technologies, such as electric vehicle-to-grid, neighbourhood batteries, and digital demand management solutions, more established approaches, such as reinforcing or undergrounding the electricity network, and systems level approaches, such as changing energy practices, strengthening the social fabric of communities and adopting different governance models.

The SμRF project contributed to these considerations in two broad ways. Firstly, by studying the appropriateness, desirability and feasibility of microgrids in the Eurobodalla region of the NSW South Coast. And secondly, by developing and demonstrating good processes through which these considerations can be undertaken, particularly with better engagement of communities.

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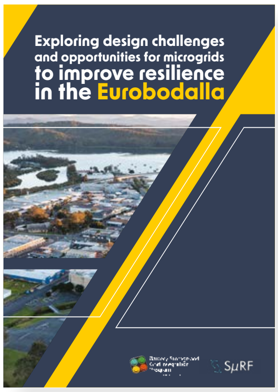
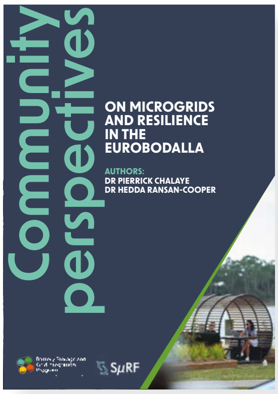
This report draws out the project's most influential findings.
Further details are available on the project website, particularly in the key reports:

Challenges and opportunities for delivering grid-tied microgrids for energy resilience

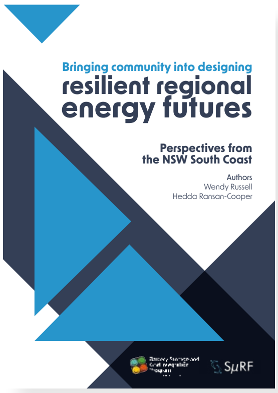
Does site selection need to be democratized? A case study of grid-tied microgrids in Australia



Exploring design challenges and opportunities for microgrids to improve resilience in the Eurobodalla



Report: Community perspectives on microgrids and resilience in the Eurobodalla



Bringing community into designing resilient regional energy futures

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What is a microgrid?

In essence, microgrids are small electricity grids.

Microgrids are **small** in terms of both their geographic footprint and their electrical capacity. They are either physically isolated from other electricity grids, or they may be 'grid-tied' and connected to other grids with switches that allow them to connect and disconnect to/from these grids. This project focused on such 'grid-tied' microgrids.

Importantly, the critical characteristic being that microgrids have the capacity to operate independently for a period of time, which is referred to as operating in 'island' mode. While there are no strict bounds on either dimension, typical microgrids serve localities such as small towns, industrial estates, and mine sites, and have peak electrical capacities roughly on the order of 0.1MW to 100MW.

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Microgrids are **grids** because they connect several properties with electricity generation and storage assets. To function as a power grid, microgrids require sufficient energy storage reserves and/or dispatchable generation capacity to reliably deliver customers' variable energy demand, as well as control systems to manage this supply-demand balance in real time. In addition to electrical control systems microgrids also need social and regulatory control and governance systems.

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For details on the types of microgrids we considered in this project see the Appendix.

What is resilience?

Energy resilience

In the energy sector, resilience is often defined in relationto reliability.

Reliability focusses on the average performance of the network including exposure to low impact, high probability events concerning static systems, such as faults, overloads or maintenance. Resilience, on the other hand, refers to the ability to restore function following high impact, low probability events such as bushfires and floods. This does not necessarily mean restoration to the same system as before the disturbance, and in fact, requires the capacity to adapt to change if better alternatives are available.

While better resilience should improve reliability, the inverse is not necessarily true. In the Eurobodalla region, for example, electricity network performs well on regulated reliability metrics but was highly vulnerable to the devastating fires and floods of 2019–2021. Another point of difference is that the objective for resilience is not prevention of the disturbance, but recovery from it, whereas reliability measures seek to prevent disturbances.

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A key insight from our study of reliability metrics is that their simplifications leave out context that is important for people, especially during disasters, and as a result resilience will not be improved if it is pursued through the same conceptual paradigm as reliability.

Resilience

Constraining the consideration of resilience to the energy system misses the crucial roles of local context and other technical – and social – infrastructures. Loss of power on a temperate day in a tight knit community of mutual aid has completely different impacts to loss of power for vulnerable and isolated community members during a heat wave.

At its heart, improving resilience is about creating the kind of future that we collectively desire. As such, there will always be some level of contestation because people have different understandings of the problem and expectations of the future.

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Rather than assume that we can sweep this under the carpet through an 'optimal' technical solution, it is important to include energy users in decision-making. In areas as diverse as municipal budgeting, to water management and infrastructure planning, we now know that involving people in decision-making leads to better, more appropriate solutions, as well as smooth project implementation as people are more likely to trust that their concerns have been addressed. In any case, public involvement in resilience planning is even more important since they need to understand the options and uses of energy during extreme events. The public are more likely to understand these options if they have been involved in the planning.

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Image: Eurobodalla Coast Tourism ©

How do microgrids relate to resilience and why else may they be of interest?

Microgrids can contribute to energy resilience in multiple ways.

Firstly, when there is an interruption to power being supplied from the upstream (larger) grid, a microgrid can seamlessly switch into islanded mode and continue to supply its connected properties with power.

Secondly, the electricity supply and/or storage capability of microgrids can contribute to the resilience of the upstream grid. They can do this by exporting (or importing) power into the upstream grid to help balance supply and demand in the larger grid.

Additionally, the ability of microgrids to operate in island mode can be drawn upon in a more planned way. For instance, during high fire risk periods (in which live electricity lines are at risk of starting fires) microgrids may be intentionally disconnected from the upstream grid so that the connecting electricity lines can be switch off ('de-energised'). This is occurring with some regularity in California.[1]

Despite making these valuable contributions to resilience, microgrids (and any technologies) have limitations in bolstering resilience. For microgrids, a major limitation relates to their access to energy to run for extended periods. Energy generation from renewable sources can be constrained by adverse weather, including bushfire smoke, clouds, hurricane winds etc. Resupply of fuels meanwhile is vulnerable to disruptions by road closures. Energy reserves within the microgrid meanwhile – in the form of liquid or gas fuels or electrical energy storage – are costly and finite.

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1 https://www.sciencedirect.com/science/article/pii/S2214629621002760

Microgrids as emblematic of 'local energy'

While the SµRF project was focused on the technology of grid-tied microgrids in the context of regional Australia, many of the issues that arose are reflective of more widespread interest in 'local energy', particularly 'community batteries'.

Many of these issues revolve around the inherent tension between parochial benefits for distinct groups against more expansive conceptions of community. For microgrids, for example, why and how should certain customers benefit from being connected to a microgrid while others do not? Similarly with community batteries, why and how should customers close to the battery receive special treatment? The focus on a small segment of the electricity network runs counter to historic social commitments, and financial investments, in poles and wires to interconnect all customers and to share these costs in an (imperfectly) equitable manner.

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Another expression of this is the high value placed on the 'self-sufficiency' of certain individuals or groups to supply themselves with solar power, devaluing the contribution of exported solar power to customers in other parts of the network. This also relates to the challenge of how to appropriately distinguish between customers who contribute solar power to the local power system, and those without solar, who do not contribute in this way, often because they are socio-economically disadvantaged.

How do microgrids relate to community expectations?

Our interviews with residents and local businesses revealed that there is significant enthusiasm for new solutions to energy needs, and for future-proofing energy systems, including the idea of microgrids.

However, many participants still have questions and concerns about whether microgrids can deliver on their specific energy needs, about the real benefits of a microgrid for the community and the environment, and about how they would be financed and work in practice.

Interviews indicated that community members' readiness and interest is influenced by their specific needs and expectations of energy services, their socioeconomic backgrounds and previous experiences, and the physical environment around their town and home.

Some were open and happy to learn more but cautious about changes to current arrangements, while others were enthusiastic and ready to start the conversation now, the main appealing aspects being community ownership, increased resilience, and environmental benefits. Interestingly, some people were so excited by the prospect of a community run microgrid that they would consider deferring investment in their own solar systems. Yet others, equally enthusiastic, preferred to push on with plans to install their own system.

> **...the main appealing aspects being community ownership, increased resilience, and environmental benefits.**

Workshops also demonstrated enthusiasm for grid-tied microgrids, which seemed to offer a solution that symbolises collective climate action, local self-sufficiency and community building. Participants wanted solutions that promote equity, fairness and community, as well as reducing environmental impacts and providing reliable and affordable power. They were attracted to the idea of community self-sufficiency. This was linked to a desire for climate action and to make use of surplus local energy, as well as a wish for more autonomy and control.

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Interviewees and workshop participants expressed a desire for community to better understand how the energy system works in order to make informed decisions and to feel in control.

Interviewees stressed that any microgrid would ideally provide continuous access to electricity during a prolonged outage to resolve resilience concerns and were sceptical that a microgrid would be the best and most practical solution. Likewise, the possibility of a microgrid providing power during extended outages was appealing to workshop participants, but more information about the technical and financial challenges (provided in the workshops) was sobering, as participants learnt of the cost and requirements for a microgrid large enough to support their communities for more than a few hours.

When participants learnt that reducing demand could significantly increase how long a microgrid could provide power, they quickly agreed on community energy use priorities. Despite acknowledging challenges with governance during emergency times, there was optimism that communities could make this work. However, community aspirations were not well supported by the current regulatory framework.

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Resilience was not seen as the only priority for microgrid design. For interviewees, operational priorities included reducing energy bills, increasing sharing capacity and local control as the top three, followed by maximising local energy supply and finding out how to reduce energy consumption. Electricity price increases was a key issue for all participants. People saw rising prices as a symptom of structural problems in energy system design and governance, and microgrids as a potential solution to this.

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In addition, many participants were disappointed with a lack of leadership, discussion and support for energy efficiency and other options for reducing energy consumption in their homes and businesses.

For interview and workshop participants, there was a strong expectation that microgrids would provide fair, equitable and universal access to electricity for the whole community, although people had different expectations of what a fair and equitable system would be like. While defining and achieving equity requires ongoing negotiation, we feel that a 'care' approach, which pays attention to vulnerability and recognises that it can affect any and all community members, in different ways, may provide for greater community resilience. This approach highlights that while grid-tied microgrids might address some forms of network vulnerability, current models are not well suited to addressing social vulnerabilities.

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Interviews and workshop discussions highlighted the lack of trust that community members have in energy companies. Their interest in community energy self-sufficiency is partly a response to this distrust in an energy system that is perceived as environmentally unfriendly, wasteful, overly complex and not serving community interests.

In terms of ownership, interview participants were keen on fully or partially government-controlled ownership, valuing transparency and accountability, but also considered community organisations like local Progress Associations. Private companies were distrusted for their profit motives and lack of transparency. Workshop participants were keen to explore community-run models.

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It became clear that there were considerable obstacles, in terms of both financial feasibility, and capacity in communities to design and run such projects. Importantly, the current regulatory arrangements prohibit some of the benefits that community members were specifically looking for, such as energy sharing within the community and independence from energy retailers. In general, the more detailed discussions in workshops highlighted the trade-offs between different values (financial benefits, environment, reliability), and the challenges of developing business models that would return benefits to the community.

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Participants' values in relation to energy system change and specifically microgrids:

Equity and fairness

– should be available to all/should redress historical inequity

Community

– should support and build community connections and social infrastructure

Environment

– should enable emissions reductions without new impacts

Accessible, relevant information

– should empower people to make informed decisions in households and communities

Reliability

– should ensure consistent, reliable power supply

Affordability

– should lead to reduced and stable electricity prices

Demand reduction and energy efficiency

– should promote measures and practices to reduce demand and raise awareness

Self-sufficiency

– should empower communities to provide for themselves and espond to emergencies

Responsiveness

– should enable responses to seasonal fluctuations and future change

What contributions could microgrids make to energy resilience?

A necessary reference point for any deliberations about the desirability of microgrids is an understanding of the degree to which they could contribute towards energy resilience.

To this end we:

- **EXAMINED** how electricity is currently used and supplied across the Eurobodalla.
- **DEVELOPED** four illustrative models for potential local energy systems, including two solar powered microgrids, a diesel generator powered microgrid and a BTM battery at a community facility.
- **CREATED** high-level conceptual designs for small and large solar microgrids for eight communities across the Eurobodalla together with costings.
- **ASSESSED** the length of time for which they could independently supply electricity.

We found that all eight communities have sufficient unshaded roof space to cover a large portion of their current electricity use from rooftop solar. However, the variability of such solar generation and electricity use makes it difficult to reliably operate any of the communities as an independent, self-sufficient microgrid for more than a few hours.

Community member's electricity consumption was shown to have the most pronounced and consistent effect. If a community were able to halve its electricity use during times were the microgrid is operating independently – which our data shows could be achieved by switching off electric hot water systems and air conditioners – such rooftop solar powered microgrids would reliably be able to operate for a day, and during sunny periods would be able to extend this to multiple days.

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The incorporation of energy efficiency upgrades as part of any energy system upgrades ought to therefore be a priority, especially as some household – for example families with young children and the elderly – may not be able to go without these appliances for health reasons.

Looking ahead, the electrification of vehicles, and other appliances, will have a large impact, both in terms of potentially doubling household electricity consumption and in terms of resilience implications of mobility to evacuate or defend properties. This will need to be factored into any specific future microgrid proposals.

For communities surrounded by cleared land capable of hosting a 4.99 MW solar farm, such a solar farm, in combination with a (realistically) large microgrid battery could be powered practically indefinitely in island mode. This result hinges on the small size of most of the communities we considered.

For the largest community of Tuross Head, with its population of 2,355, a 4.99 MW solar farm is insufficient to balance community electricity consumption.

The limitations of solar powered microgrids bolsters the case for diesel generator powered microgrids, which are also the cheapest systems to deploy. The flip side of this is that their benefits are limited, if used only during rare occurrences of grid outages, or tarnished by excessive pollution emission, if they are used routinely.

The preliminary business cases developed for the solar powered eight communities all fall far short of economic feasibility under current regulatory arrangements as the value they create beyond simple solar generation, such as potential resilience improvements and assistance with network management in the presence of large amounts of rooftop solar and electrified appliances, cannot be monetised.

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The governance required to build resilience going forward

Improving energy resilience starts with challenging current assumptions

Interviews with energy stakeholders revealed important and deeply held assumptions about governance that shape people's appetite and openness to reform for resilience. For example, there is genuine concern for some participants inside market bodies about changing any rules that might challenge the principle of competition that underpins the mechanism for accountability/efficiency in the national electricity rules.

As such, any alternatives to the current system are often viewed through a strongly techno-economic framing. Such a framing appears out of step with the evidence base around what can lead to a more resilient system and more than certainly will create blind spots. This tension would need to be resolved before regulatory reform could progress.

A key concern and tension around improvements to resilience emerged for stakeholders around the level of uncertainty and consistency in climate modelling coupled with a lack of understanding about what solutions may best improve resilience.

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Local solutions need to demonstrate cost-effectiveness so that the principles of equity and efficiency are not undermined since network costs are spread across all users in the network. At the same time, because of the growth of local energy assets (rooftop solar/battery systems) network resilience now covers a policy domain that is separate from Networks – because of vertical disaggregation. This creates new complications for assessing and creating solutions for energy resilience. The resultant regulatory complexity will likely be a major challenge in localised attempts to build resilience.

Stakeholders with a lot of experience in community contexts articulated that there is a strong desire for localised solutions. People are attracted to local solutions around domains like food and energy because they feel such systems can provide more accountability, sustainability benefits and authentic relationships between consumers and the people that maintain critical systems.

This interest and desire for local solutions may be a cultural change that is not well understood or recognised by many policy and industry professionals. While these stakeholders believed in community involvement and engagement, they were generally cautious of communities' ability to self-organise and hold sole responsibility for managing these systems. As such institutional trust is likely to be a core part of delivering future solutions around improving resilience.

Capacity building will be needed

The theme of capacity-building emerged as being significant across our interviews and is also a theme that is covered in the literature review. Generally speaking, energy professionals believed Networks have not been enabled to build capacity to anticipate and design for the future. They also believed in the need to include the public in resilience planning, a point that was raised in resilience metric development. An implication is that not only will there be a need to build skills and capacity about institutional flexibility and anticipating the unexpected, but also that there will be a need to bring on professionals skilled in community development and engagement.

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approach, as covered in the literature review. The local scale is important for communication, coordination and service delivery, as well as engagement as already discussed. Stakeholder interviews revealed that local government and regional Network depots are important local institutions in extreme events. But while many placed a lot of expectation on local government, viewing them as in the 'sweet spot' of having institutional capacity and accountability, while being able to deliver local services, local government themselves held a different view.

Local government intervieews spoke of increasing expectations from them of service delivery without adequate resourcing. Their funding base has not traditionally been set up to cover the sorts of sustainability and resilience solutions that the community increasingly expect of them. If local governments are expected to form part of resiliency solutions both their resourcing and organisational cultures will likely need to shift.

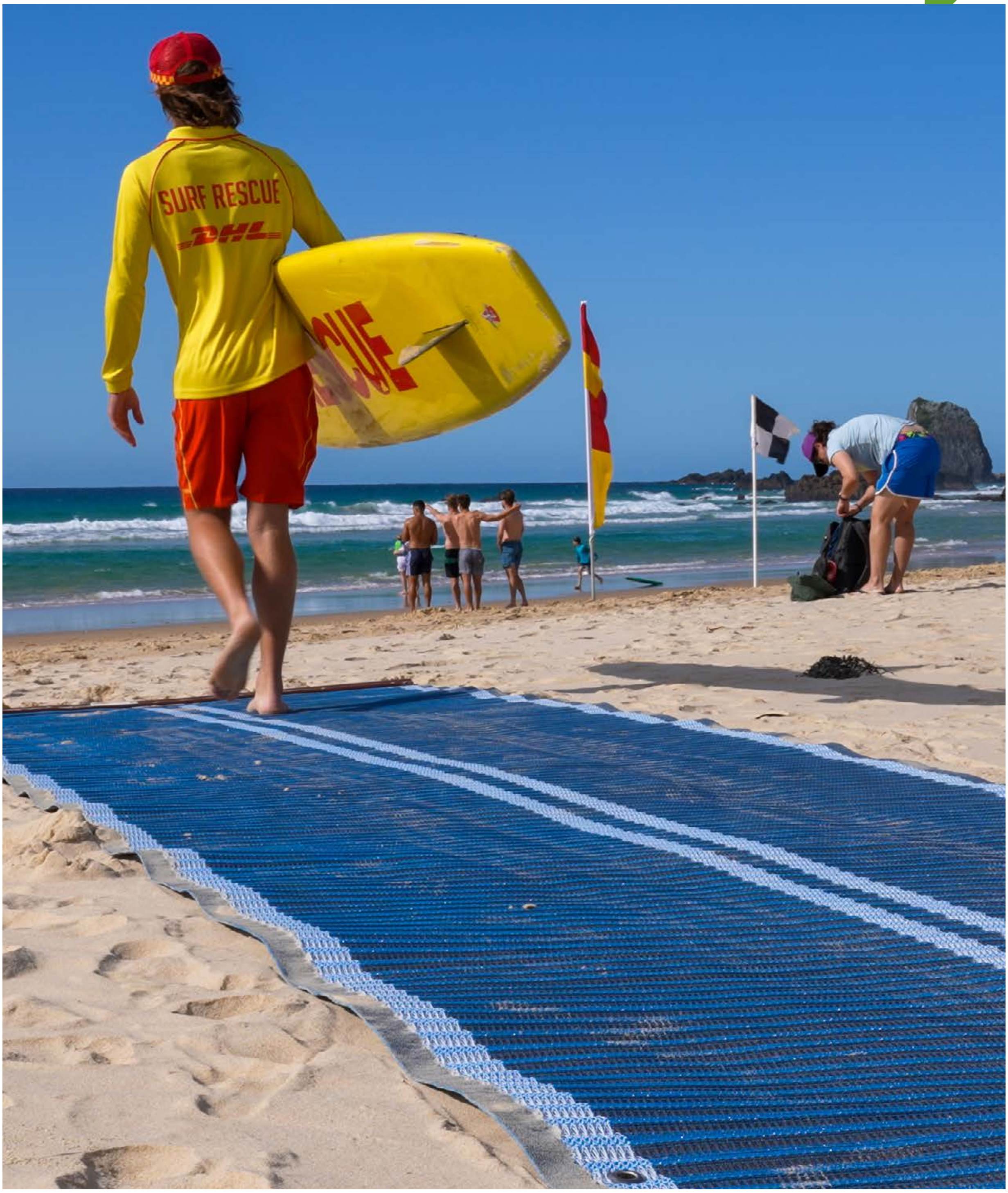

Image: Eurobodalla Coast Tourism ©


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Conclusion and next steps

In conclusion, resilience, and vulnerability, are highly dependent on socio-economic arrangements and infrastructures, as well as physical infrastructures. Microgrids can therefore at best address one component of resilience, while simultaneously being shaped by socio-economic circumstances and goals.

At present, there are significant gaps between the capabilities and costs of grid-tied microgrids and the expectations and desires of communities. Contributing factors of which include the prohibative cost of batteries that can store the amount of energy required for extended power supply after major events; the inability to monetise resilience improvements as well as other network services that microgrids could offer, and; the equity implications of localised energy systems that include some community members and exclude others.

Ultimately, energy resilience and decarbonisation are systemic transitions that require engagement and actions from a great many actors, from individuals to national institutions. The issues of how these transitions are governed – who is involved, how they collaborate, how decisions are made and popularised – have stood out as the most pertinent of all issues covered in SμRF. While responsibility for this governance is distributed across many – and we make some specific suggestions – responsibility for leading and coordinating these processes ultimately rests with the federal government and national institutions.

Appendix

What kinds of microgrids are plausible for the Eurobodalla and regional Australia?

In the interest of balancing the uncertainties around what form microgrids may take in the future with the need for a tangible hypothetical to analyse and discuss, the SµRF project devised a set of four archetypal energy systems that were used throughout the project.

These consisted of three microgrids together with a battery installed behind-the-meter (BTM) at a single site.

Given the eight Eurobodalla communities all have strong, reliable connections to the Australian National Electricity Market (NEM), our scenarios all consider the microgrids to remain connected to the NEM for the vast majority of the time – facilitating both power imports and exports with other parts of the country. The microgrids only switch to islanded operation when there is a fault in the upstream grid (that without the microgrid would cause a loss of power to the community).

The defining features of the four energy systems are as follows:

A BTM battery (not a microgrid)

A battery installed in a community facility – such as a town hall, fire station, or emergency shelter – can provide a (modest) amount of backup power for use during grid outages. During disaster events, such as fires and floods, the battery capacity would enable personal and emergency devices to be kept charged, as well as potentially some degree of space or fridge cooling. If the facility had rooftop solar (and an appropriate inverter) it may be able to provide power over multiple days.

During normal grid conditions the battery can provide other services for the community facility, such as storing electricity generated by rooftop solar and reducing electricity bills, although the extent to which these are pursued will be constrained by wanting the battery to be near full state of charge at all times in preparation for an unexpected grid outage.

A small solar microgrid

In our first microgrid model, solar panels are deployed onto every sunny roof in a community. When the microgrid is islanded from the NEM, these solar panels are the sole source of electricity generation. The second major component of the microgrid is a battery, which is sized relative to the communities' electricity needs and is imagined to be installed within the streetscape of the community. Lastly, the microgrid will require some switch gear at the points of interface of the NEM and the microgrid.

During normal grid conditions the battery and control system of such a microgrid will be able to assist in the secure and reliable operation of the local distribution network, particularly assisting with accommodating increased amounts of rooftop solar and electrified appliances such as electric vehicles. These are services that may be valued in a business case.

From a resilience perspective, the advantage of this model is that it reduces the exposure of the infrastructure to bushfire damage. While the Black Summer bushfires did indeed burn dwellings in many towns in the Eurobodalla, it is expected that firefighting efforts would generally focus on townships. Locating infrastructure in existing towns, reduces the infrastructure requiring protection in extreme fire events.

This type of microgrid has been deployed in Mooroolbark[2] (Vic) and is being deployed in Bawley and Kioloa[3] (NSW).

2 https://power-tec.com.au/mooroolbark-mini-grid-22h-off-grid-operation-proves-sharing-renewable-energy-alleviates-power-outages/

3 https://yoursay.endeavourenergy.com.au/bawley-point-kioloa-community-microgrid

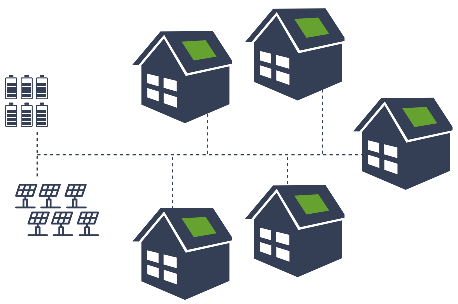
A large solar microgrid

The second microgrid model builds on the small solar microgrid model with the addition of a solar farm. The battery storage capacity is also increased, with the battery assumed to be co-located with the solar farm. This model requires access to a considerable amount of cleared land for the solar farm and is only conceivable for a subset of the communities.

During normal grid conditions the major feature of such a microgrid is the power generation from the solar farm. This may be a major source of revenue and may cross subsidise the battery storage and microgrid assets and capabilities.

From a resilience perspective, such larger infrastructure provides the potential for far greater power supply, however this potential is still critically reliant on sunshine and so may come to nothing if the sky is blocked with smoke or clouds. The solar farm may also add additional terrain needing protection from natural hazards, thereby stretching resources.

This type of microgrid (using a wind farm rather than a solar farm) has been deployed on the Yorke Peninsula[4] (SA).



A diesel microgrid

The third and final microgrid model uses diesel generators to power communities. These generators would be able to provide all of the communities' electricity demand for as long as they have fuel.

The use of diesel generators will emit substantial carbon emissions (and other pollution) whenever they run. This may not be a major issue if they are only used during infrequent natural disasters but would become of greater concern if they are used more frequently, such as to provide network management services. This emission intensity creates a direct tension with the financial business case, in which more regular use improves the return on investment.

From a resilience perspective, large reserves of diesel present a major hazard to be managed during fires or other natural disasters. The resupply of fuel reserves from outside of the community meanwhile is vulnerable to being interrupted by road damage/closure.

4 https://www.electranet.com.au/electranets-battery-storage-project/