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

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

SμRF

Acknowledgements

We acknowledge, respect and celebrate Aboriginal people of the Yuin Country as well as the Ngunnawal and Ngambri people (ACT), on whose land this research was conducted and pay our respects to Elders, past, present and emerging.

There were many contributors to this report. Firstly, we would like to thank the Eurobodalla households and businesses who allowed us to install energy monitoring devices in their properties and utilise the resultant data in this report.

We would also like to acknowledge the work of Zepben in developing the distribution network vulnerability tool and ITP Renewables in preparing the microgrid designs and costings.

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A partnership between

Australian National University

essential energy

SHASA Southcoast Health and Sustainability Alliance

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Front cover image: Eurobodalla Coast Tourism ©

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Executive summary

Microgrids may present appealing benefits to communities across regional Australia, such as bolstered resilience and/or increased utilisation of renewable energy sources. The degrees to which microgrids can deliver such benefits depends on many factors, and must be weighed up against unresolved issues of affordability, accessibility, and microgrid governance.

This report focussed on the design challenges and opportunities for microgrids to improve resilience in the Eurobodalla region of the South Coast of NSW. Community expectations, and operational and business model considerations are covered in other project reports.

We examine the technical requirements of microgrids in the Eurobodalla in four broad parts:

1. Quantifying the way in which electricity is currently used and supplied across the Eurobodalla.
2. Developing four illustrative models for potential local energy systems, including a BTM battery at a community facility, two solar powered microgrid options and a diesel generator powered microgrid.
3. Creating high-level conceptual designs for small and large solar microgrids for eight communities across the Eurobodalla and assessing the length of time for which they could independently supply electricity (in what is called 'islanded' mode).
4. Compiling cost estimates for each of the microgrid models in the eight communities.

Collectively, these examinations suggest four pointers for future development.

Firstly, in all the considered (eight) communities there is sufficient unshaded roof space to generate enough solar electricity to cover a large portion of the communities' current electricity use. 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. However, were a community as a whole able to halve its electricity use during times where the microgrid is operating independently, 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.

This highlights the fundamental importance of community members' electricity consumption. The analysis of electricity use in properties across the Eurobodalla indicates that reducing electricity consumption by half during an emergency scenario is well within the realms of feasibility, being equivalent to switching off electric hot water systems and air conditioners – for those properties who have these appliances.

However, it should be noted that some household types – e.g. families with young children and the elderly may not be able to go without these appliances for health reasons. The incorporation of energy efficiency upgrades as part of any energy system upgrade would contribute towards demand reduction – and ought to be a corner stone of any energy system evolution. In contrast, the move to 'electrify everything' will increase demand for electricity and make the resilient supply of electricity even more critical. The electrification of vehicles will have the largest impact, both in terms of potentially doubling household electricity consumption, and in resilience implications of mobility, to evacuate or defend properties. This will need to be factored in to any specific future microgrid proposals.

Secondly, where communities are able to accommodate a 4.99 MW solar farm close to town, these solar farms are generally able to power the community indefinitely in independent operation – in the presence of a large (but realistic) battery. This result hinges on the small size of most of the communities we considered; for the largest community of Tuross Head a 4.99 MW solar farm is insufficient to balance community electricity consumption.

Thirdly, an issue that is only beginning to be studied, but which needs to be factored into conceptions of solar powered microgrids, is the reduction of solar irradiance[1] during natural disasters – from rain clouds or bushfire smoke. One study of the 2019–20 Black Summer fires[2] found that solar generation during the fires was generally better than solar generation during winter. Furthermore, the occurrences of consecutive days of low solar generation were less frequent during the fires than during winter. This suggests that microgrids designed to operate year-round may operate reasonably well during natural disasters, however this will depend on the specific weather conditions and microgrid capabilities. This risk bolsters the case for diesel generator powered microgrids.

The fourth key finding is that diesel generators are by far the cheapest systems to deploy. They would however produce significant pollution if used routinely or they would provide limited benefits, if used only during rare grid outages.

Ultimately, the outcome of this study is not to dictate a specific a preferred choice of microgrid design, or even whether microgrids are suitable for the Eurobodalla or regional Australia. Rather, the analysis has surfaced a number of issues for consideration about the feasibility and desirability of microgrids, particularly in relation to resilience. The analysis has provided important inputs into other SμRF project activities and outputs include the individual business and implementation plans for the eight communities. More broadly, these issues will need to be to be weighed up in any deliberations of how microgrids may feature in the evolution of the energy system to be resilient to the stresses of, and compatible with mitigating further worsening of, climate change.

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[1] https://en.wikipedia.org/wiki/Solar_irradiance

[2] https://energy-resilience.com.au/wp-content/uploads/2023/08/ESKIES-Report-2023-08-17.pdf

Introduction

The SμRF project is exploring the potential for microgrids to improve the resilience of the energy system in the Eurobodalla region of the South-coast of Australia.

The project is designed to consider a diversity of contexts within this region, as well as a diversity of potential microgrid configurations, so as to produce insights that can be translated to communities across regional Australia.

One aspect of this work is to assess the design challenges and opportunities for microgrids to improve resilience in the Eurobodalla communities, with a particular focus on energy resilience. This helps define what energy systems are technically possible for these communities and, more narrowly, what systems might be practical. This information is used throughout the SμRF project, in our social research with community and businesses and as the basis for developing business cases for various potential microgrid systems.

The lens of technical possibilities and practicalities complements the other analyses conducted for the SμRF project, which are covered in other reports available at bsgip.com/research/projects/.[3]

The report is structured around the following key questions:

5. How is electricity used in the Eurobodalla?
6. How vulnerable is the electricity supply in the Eurobodalla?
7. What is a microgrid and how could they improve energy resilience?
8. What microgrids could work in the Eurobodalla?
9. What sized microgrids could be practical for the Eurobodalla?
10. How long could solar powered microgrids operate for independently in 'islanded' mode?
11. How much do microgrids cost?

Some of these questions (2 and 7) are the subject of standalone reports. These are briefly summarised in this report, with readers directed to the respective reports for further discussions.

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[3] https://bsgip.com/research/projects/southcoast-%c2%b5-grid-reliability-feasibility-s%c2%b5rf-project/

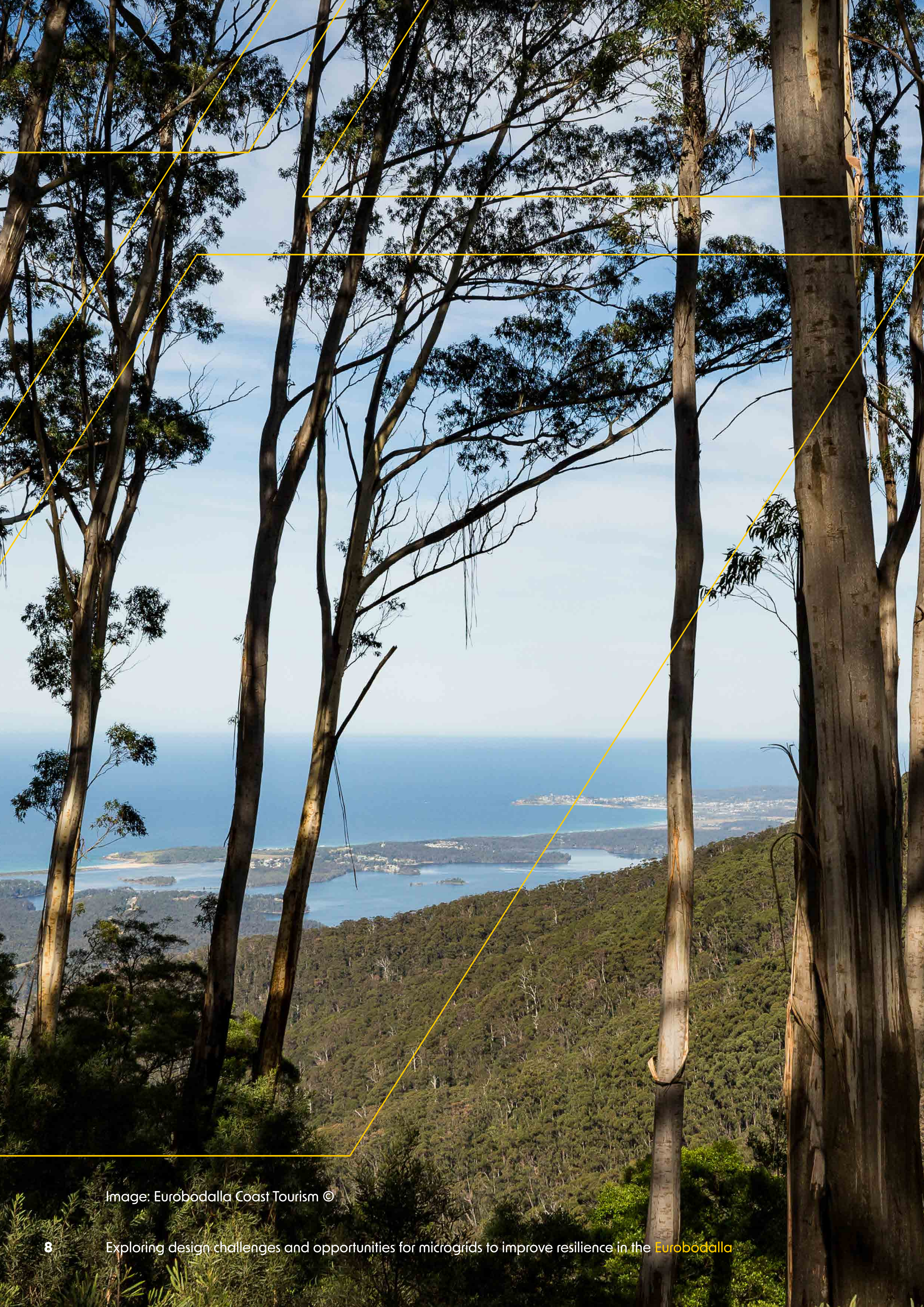

Image: Eurobodalla Coast Tourism ©

How is electricity used in the Eurobodalla?

In line with the SμRF project's goal of capturing (some of) the diversity of communities across regional Australia, the project team selected eight communities for detailed study. These are: Tuross Head, Nelligen, Bodalla, Broulee, Mystery Bay, Congo, South Durras, and Central Tilba and Tilba Tilba (treated as one).

For further details on the methodology for site selection see our working paper, 'Does site selection need to be democratised? A case study of grid-tied microgrids in Australia'[4] and the implemented assessment spreadsheet 'A framework for responsible project site selection'.[5]

Adopting these eight communities as our sample points, we begin our analysis with aggregate demand data from the Essential Energy substations serving each community. Figure 1 shows that electricity consumption varies substantially between communities, with the average of 16.5 kWh/day being a little higher than the average across the Essential Energy network of 15 kWh/day[6]. This may be due, in part, to none of these communities being connected to a gas network.

While we lack data to explain this variation, some factors could include:

- Beach towns with high proportions of holiday houses tend to have low consumption as these properties are frequently vacant (South Durras, Mystery Bay, Broulee).
- Communities with a higher proportion of businesses use more electricity (Bodalla, Tilbas).
- Congo, Tuross Head and Nelligen do not fit into these trends. They all have high levels of residential property occupancy and low proportion of businesses but have widely varying rates of electricity use, with Congo and Tuross Head having low usage while Nelligen having very high usage (twice the rate per property of Congo). This demonstrates the impact that differences in the built environment, appliances and human behaviour can have.

Further analysis of these consumption patterns would be valuable, as the substantial differences will impact the effectiveness and feasibility of microgrid systems. They may also highlight opportunities for easy energy efficiency upgrades.

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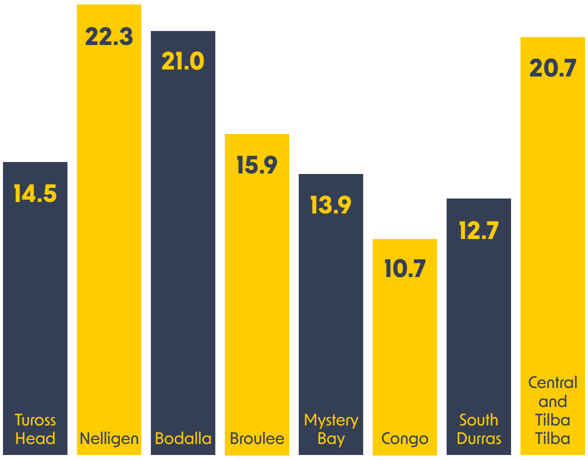
[4] https://hal.science/hal-04187386

[5] https://bsgip.com/wp-content/uploads/2022/06/A-framework-for-responsible-project-site-selection-SuRF-case-study.xlsx

[6] https://www.aer.gov.au/system/files/Residential%20energy%20consumption%20benchmarks%20-%209%20December%202020_0.pdf

Figure 1 Average daily electricity consumption in kWh per property/per day for the eight Eurobodalla data sets based on Essential Energy substation data.



To complement this community wide data, we next examine granular electricity data for individual properties on a five-minute-by-five-minute basis. This provides insights into the variations of electricity across space (properties) and time (as a function of the seasons, weather, and human activity).

This data was sourced from 71 Wattwatchers energy monitoring devices deployed by the SµRF project in homes and businesses across the Eurobodalla.

Figure 2 presents the daily electricity consumption averaged across the properties for the nine-month period from 1 November 2022 to 31 July 2023. Across this period, which is slightly biased towards winter months, the average consumption is 14.3 kWh per day per property – slightly less than the comparative figure in the substation data. As expected, consumption tends to peak in the hottest parts of mid-summer and the colder, darker weeks of mid-winter, with winter causing the more substantial increase. The variation from day to day is significant, regularly exceeding 5 kWh (30%).

Figure 3 provides another view on this data, complementing the average consumption per property – shown as the solid black line – with the distribution of properties – indicated by the coloured region that spans between the 32nd and 68th percentiles. The tendency for the average value to sit towards the top of the distribution indicates that the average is being pulled up by a small number of high demand properties, with the majority of properties consuming less power than indicated by the average.

Figure 2 Average daily electricity consumption per property in the Eurobodalla data set

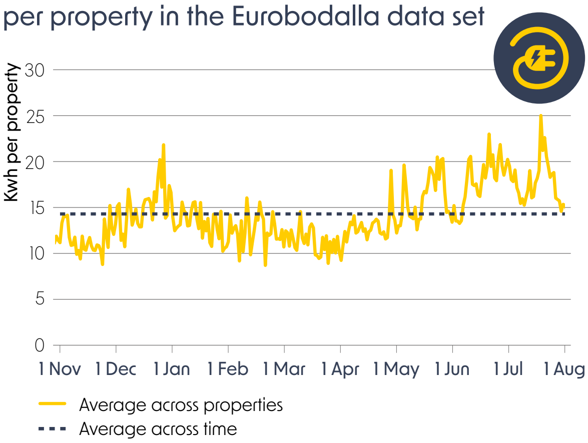
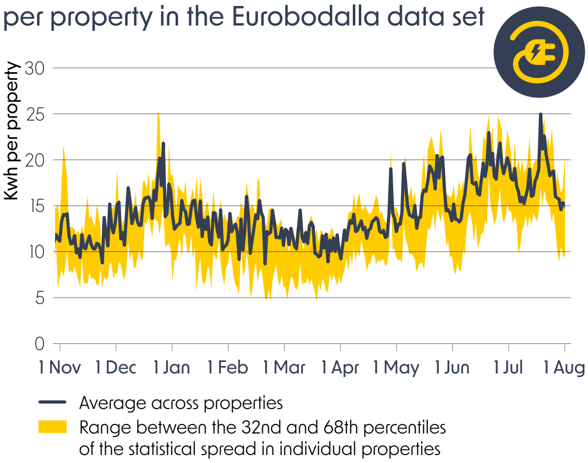


Figure 3 Variation in daily electricity consumption per property in the Eurobodalla data set

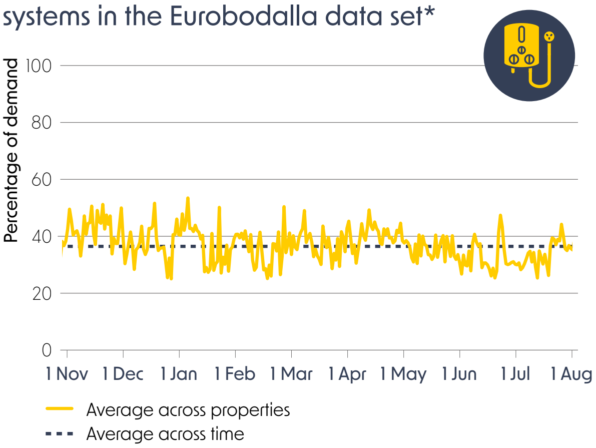


Another insight from the Wattwatchers data is that it provides circuit level data – at least when monitoring devices are installed appropriately. For our analysis, we focus on two particular uses of electricity that are common across the Eurobodalla (and regional Australia) and which consume significant amounts of electricity. Namely, electric hot water systems (our data does not specify whether units are resistance type or heat pump type) and air conditioners (which we assume to provide both cooling and heating functionality).

Figure 4 shows that electric hot water systems represent on average 36.4% of the total electricity consumption of Eurobodalla properties (in those properties where Wattwatchers were configured to explicitly distinguish hot water units). Furthermore, this proportion is observed to be quite constant across the seasons and weather.

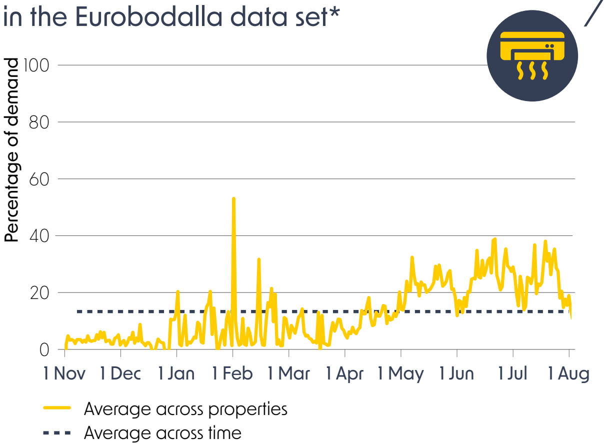
Figure 5, meanwhile, shows that, for those properties where air conditioners were identified and monitored, these units made up 13.3% of properties' electricity use. Taken together, as presented in Figure 6, this data indicates that electricity demand could conceivably be cut in half if customers switched off their electric hot water systems and air conditioners – a point to which we will return to in later scenario analysis.

Figure 4 Percentage of customers' electricity consumption used by their electric hot water systems in the Eurobodalla data set*



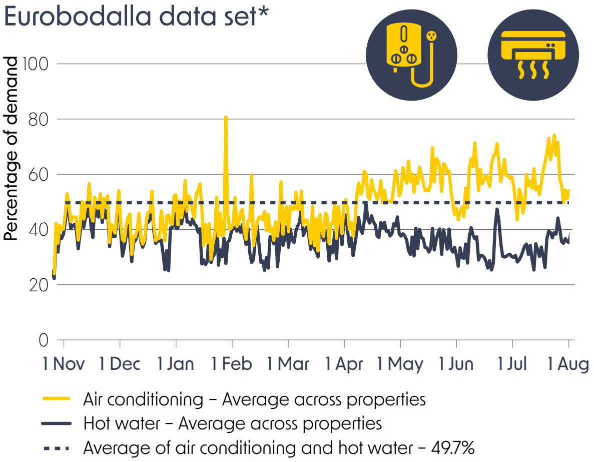
* Of those properties with dedicated water heater data

Figure 5 Percentage of customers' electricity consumption used by their electric air conditioning systems (heating and cooling) in the Eurobodalla data set*



* Of those properties with dedicated air conditioner data

Figure 6 Percentage of customers' electricity consumption used by their electric hot water systems and air conditioning systems in the Eurobodalla data set*



* Of those properties with these devices monitored by dedicated circuits

Figure 6 shows

49.7%

of all electricity consumed was used for electric hot water and air conditioning systems.

Solar generation in the Eurobodalla

Most research participants who had a Wattwatcher electricity monitor installed have rooftop solar systems. In this next section, we analyse the energy generation performance of the solar systems in absolute terms and in proportion to customer's electricity usage.

Figure 7 shows the daily solar generation, average across those properties with solar systems, in units of kilo Watt hours (kWh). Across the nine-month period, with its mild bias towards winter's shortened sunshine days, the average generation is 17.0 kWh per day. The day-to-day and seasonal variation in solar generation is seen to be even greater than the variation in electricity consumption (Figure 2).

Figure 7 shows average generation

17.0kWh

per day

Figure 8 shows rooftop solar systems produce

25.3%

more electricity than these customers used

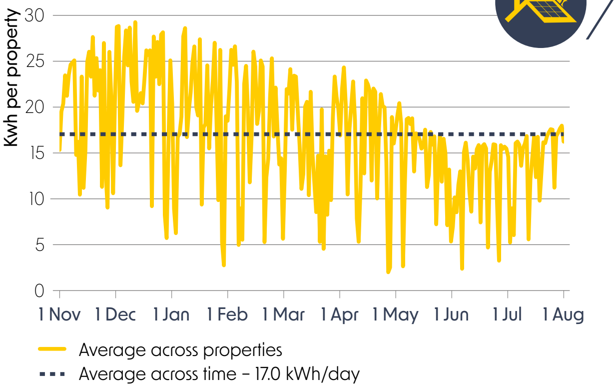
Image: istock by Getty Images Douglas Cliff

Figure 8 puts this solar generation into perspective for these householders by presenting the same solar data as a proportion of customers' electricity consumption (for the subset of customers that have rooftop solar systems). Across the period from 1 November to 31 July these rooftop solar systems produced 25.3% more electricity than these customers used. This is an encouraging finding for the prospect of self-sufficiency for the community, however this average quantity masks two crucial details:

1. Electricity demand must always be met with electricity supply on a (fraction of a) second-by-second basis. Looking at the recorded Eurobodalla data in more granular detail (in five-minute increments) reveals that electricity usage is distinctly out of sync with solar generation. This is illustrated in Figure 9 for a randomly selected property. The misalignment of demand and generation are representative of all the properties monitored in the Eurobodalla for this project as well as other data sets for residential properties – as is the highly volatile nature of demand.
2. Electricity is expected to be available every day. The shortfall of solar generation on cloudy days and short daylight months is therefore a challenge that would need resolving.

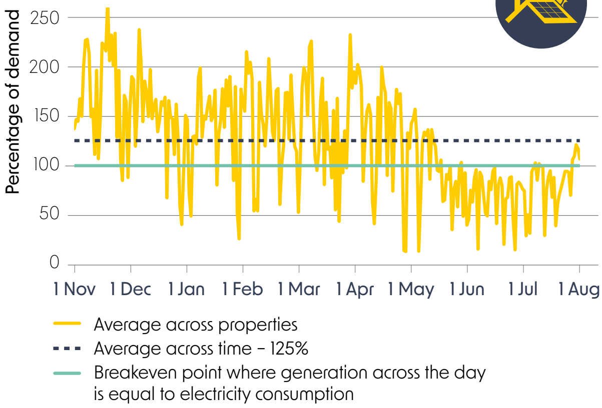
These considerations emphasise the importance of having some excess electricity generation capacity and energy storage in energy systems – including the national grid and microgrids – to ensure electricity supply can balance demand across the day and across the year. Furthermore, it provides an insight into the role that diversity – of customer demand and generation assets – can play in smoothing demand and generation patterns to make it easier to reliably balance supply and demand. The advantages delivered by diverse sources of generation is one of the motivations for creating large, interconnected grids instead of having every property (or town) operate off grid.

Figure 7 Average daily solar generation (kWh) per property in the Eurobodalla data set*



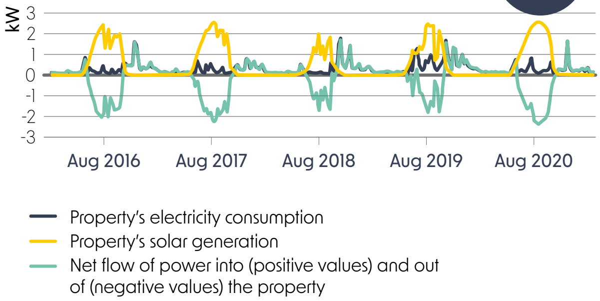
* For those properties that have solar

Figure 8 Average daily solar generation as a percentage of each property's electricity consumption in the Eurobodalla data set*



* For those properties that have solar

Figure 9 Electricity consumption and solar generation profile in five-minute intervals for a randomly selected property from the Eurobodalla data set*



* This property is representative in its volatile electricity use and large temporal mismatch between solar generation and electricity consumption (leading to large amounts of power being exported to the grid).

Conclusion How electricity is used in the Eurobodalla

Based on this analysis we can make the following comments about electricity usage in the Eurobodalla:

Across the eight studied communities each property uses an average of

16.5 kWh

of electricity per day. This is pretty typical for the (mostly regional) communities connected to the Essential Energy network (whose footprint covers 95% of NSW).

There is great variation in electricity consumption between communities – with some using

twice

as much as others. Low usage communities will be significantly easier to supply with microgrids (or any other energy system).

The properties equipped with energy monitors demonstrate large variation in electricity demand across each day and from day-to-day.

Day-to-day changes of over

30%

are not uncommon and seasonal changes are of a similar magnitude.

Electric hot water systems and air conditioners represent

36%

and

13%

of the electricity consumed by those properties that have these appliances.

Switching these appliances off would therefore reduce these properties' consumption by half.

On many days, rooftop solar is producing more than enough energy to cover properties' consumption, however the

timing

of the solar generation is mismatched to when properties use electricity and there are many days on which solar generation is less than consumption.

Image: Eurobodalla Coast Tourism ©

Comparison with how electricity is used in Canberra

Because the data we have for the Eurobodalla is somewhat limited – in terms of number of properties and length of time – analysis for microgrid designs will make use of the extensive Nextgen data set, which covers hundreds of properties in Canberra, ACT. While this data set spans multiple years, we narrow our analysis to data from 2018, which has been thoroughly cleaned and verified.[7] Before doing so, we assess the similarity of the NextGen data to the Eurobodalla data by repeating the analysis of per property electricity use and solar generation (Figures 2, 7 and 8).

Figure 10 contains the average daily electricity consumption of properties in the NextGen data set (with the calendar year 2018 data rearranged to match the November to August timeframe of the Eurobodalla data). This shows a few differences. Firstly, consumption is far higher in the NextGen data, averaging 24.8 kWh per day per property, compared to 14.3 kWh in the Eurobodalla data.

While interesting in its own right, this won't affect our scenario analysis because we will rescale the property consumption data to match the community specific values set out in the substation data (Table 1). The second difference is that the NextGen data features greater peaks in consumption on hot summer days and during the cold Canberra winter. These features will flow through to our scenario analysis. Their impact will be to place a greater strain on the microgrid, thereby skewing our results (modestly) towards conservatism.

Firstly, consumption is far higher in the NextGen data, averaging

24.8kWh

per day per property, compared to

14.3 kWh

in the Eurobodalla data.

The analysis of the NextGen solar data is presented in Figures 11 and 12. While the per property solar generation is higher, averaging 25.1 kWh per day, this isn't quite enough to match the larger consumption, so that solar generation is only 14.2% greater than consumption across the period. This also won't affect our scenario analysis as the solar capacity is rescaled based on hypothetical microgrid designs. The day-to-day and seasonal variations in solar generation are consistent with the Eurobodalla data.

...this won't affect our scenario analysis because we will rescale the property consumption data to match the community specific values set out in the substation data (Table 1).

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[7] Described in https://dl.acm.org/doi/10.1145/3307772.3331017

Figure 10 Average daily electricity consumption per property in the NextGen data set

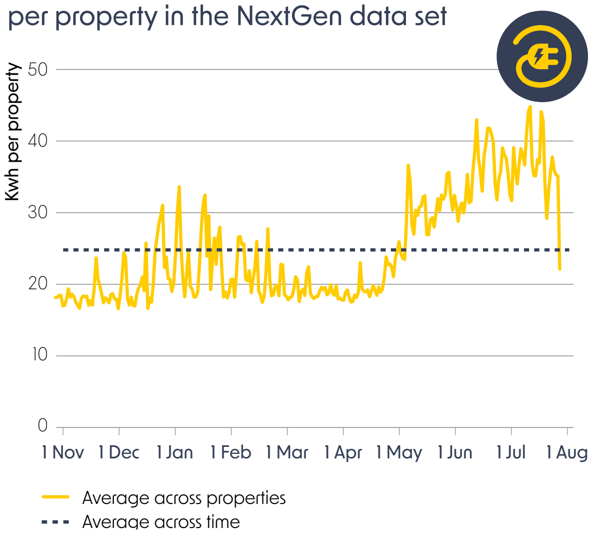


Figure 11 Average daily solar generation (kWh) per property in the NextGen data set

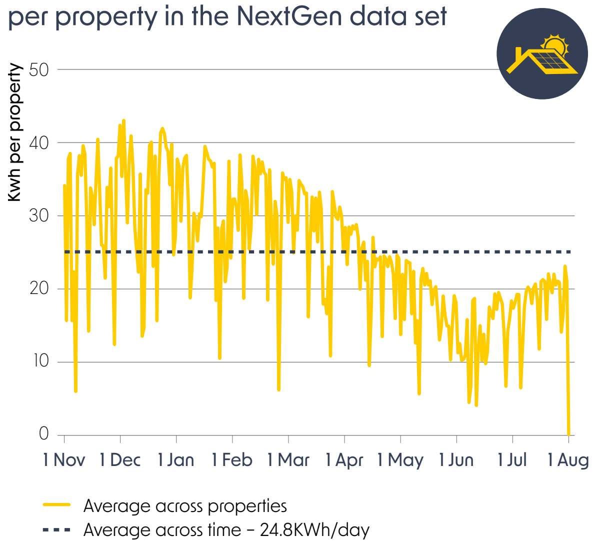
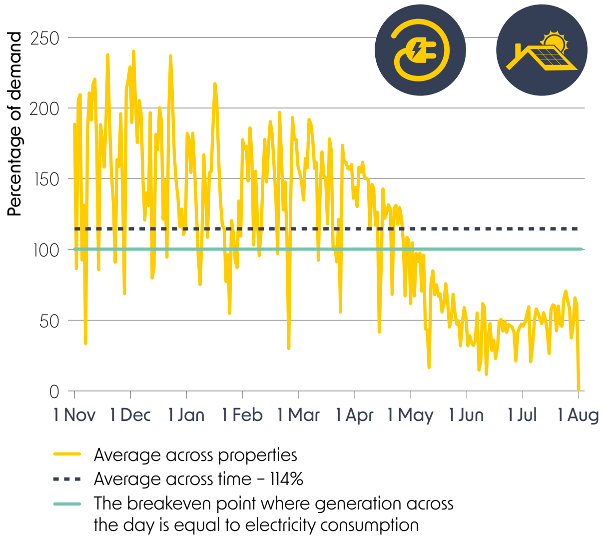


Figure 12 Average daily solar generation as a percentage of each property's electricity consumption in the NextGen data set



While the per property solar generation is higher, averaging

25.1kWh

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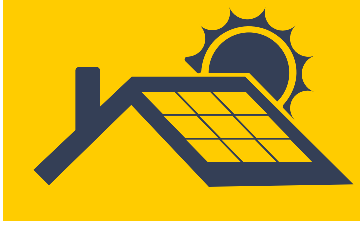


Image: Eurobodalla Coast Tourism ©

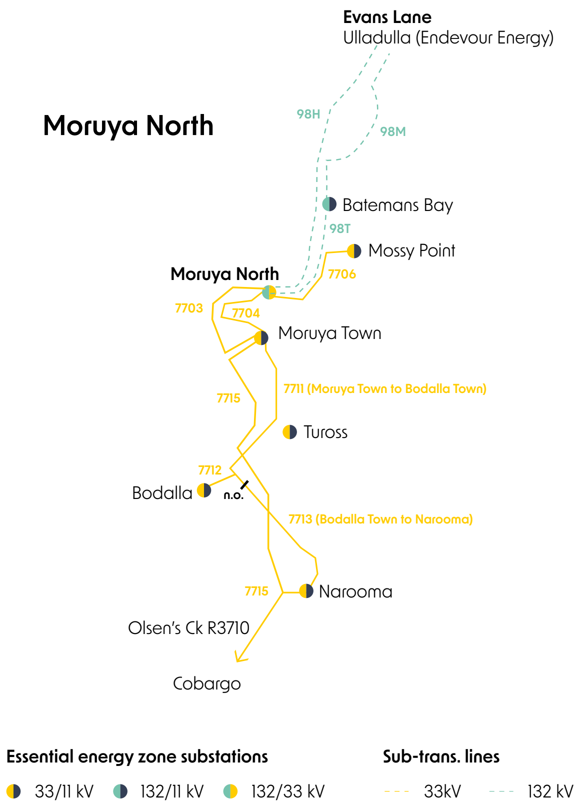
How vulnerable is the electricity supply in the Eurobodalla?

The previous section outlines how electricity is used across properties and communities in the Eurobodalla. The next question that arises in the consideration of energy resilience for the Eurobodalla is 'how vulnerable is the electricity supply in the Eurobodalla?' This is particularly pertinent after the region's recent experiences of widespread fires and floods.

As background context for issue, Figure 13 presents a schematic of the electrical backbone (the 'sub-transmission network') that connects the Eurobodalla to the national grid ('transmission network').

To explore the question of vulnerability, SµRF project partner Zepben performed a comprehensive analysis of grid outages across the Eurobodalla across many years. Zepben analysed the susceptibility of each part of the Eurobodalla electricity network to damage (the frequency of disruptions), and the impact that disruptions to any network component would have on the supply of electricity to local customers and communities (the severity of disruptions).

Figure 13 Sub-transmission single line diagram of Moruya North area[8]



This involved:

- Collating a comprehensive collection of network mode data and records of historic fault and network performance statistics.
- Analysis of the historic network performance, to determine dependant and independent segment level performance.
- Characterisation of network performance as expected fault rates and repair time.
- Synthesising variables to derive a quantified vulnerability metric for each network segment.

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[8] https://dapr.essentialenergy.com.au/essential_data/DAPR_Essential%20Energy_2022_Final.pdf

Figure 14 presents an illustrative example output from this analysis for network feeder MPTD2, which services Rosedale, Guerilla Bay, Malua Bay, and parts of Mossy point and Surf Beach. In this case the red lines indicate highly vulnerable network segments, orange lines indicate medium vulnerability and green lines low vulnerability. This map view makes clear how vulnerability increases towards the ends of the network due to ever greater lengths of distribution lines connecting these areas to the core of the network. Local conditions are clearly also influential, with equally remote segments experiencing different levels of vulnerability.

> **Overall, the results indicate that the Eurobodalla network is providing customers with**
> **relatively reliable**
> **power supply, for the context of regional communities surrounded by expansive bushland. Crucially, none of the feeders are performing poorly enough to meet the network upgrade investment test...**

Figure 14 Vulnerability analysis of network feeder MPTD2 in the Eurobodalla

🟩 SAIFI <2.2
🟧 SAIFI <8.4
🟥 SAIFI <8.4

SAIFI is the average number of interruptions that a customer would experience

The findings of this study are summarised in Table 1, which presents the vulnerability of each Eurobodalla feeder to outages and the average duration of outages on each feeder. Overall, the results indicate that the Eurobodalla network is providing customers with relatively reliable power supply, in the context of regional communities that are surrounded by expansive bushland. Crucially, none of the feeders are performing poorly enough to meet the network upgrade investment test set by the Australian Energy Regulator.

For full details on the methodology and software tool, see Zepben's 'Vulnerability Assessment Report'.[9]

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[9] https://bsgip.com/research/projects/southcoast-%c2%b5-grid-reliability-feasibility-s%c2%b5rf-project/

Table 1 Summary of distribution network vulnerability statistics across the Eurobodalla

Feeder (North to South)	Localities	Vulnerability to interruption (interruptions p.a.)	Consequence of interruption (av. duration mins)
BBYH2	Part of North Batemans Bay, Benandarah, Depot Beach, North and South Durras, East Lynne, Nelligen and Currowan	🟧 32.7014539	🟨 117.7264056
BBYF2	West Batemans Bay, Edgewood, Lilli Pilli, Runnyford	🟧 31.99194172	🟥 476.0644446
MPTC2	Mossy Point, Broulee	🟩 5.072343646	🟨 81.04287554
MPTD2	Rosedale, Guerilla Bay, Malua Bay, part of Mossy point and part of Surf Beach	🟧 21.01816456	🟥 415.838309
MPTB2	Barlings Beach, Tomaga River	🟩 4.395155147	🟩 49.97002841
MPTA2	Jeremadra, Mogo	🟩 3.993815	🟩 11.91448905
MYT3B6	Moruya Airport, Moruya Heads, part of Moruya and part of Broulee	🟨 14.32561343	🟩 55.16201566
MYT3B7	Congo, Coila and Bingie	🟧 22.51272585	🟩 56.51300142
BODB2	Trucketabella, Turlinjah, Tuross Lake	🟩 5.226565617	🟩 7.890955621
TURA2	Tuross Head	🟩 8.982649785	🟨 110.9466497
BODC2	Potato Point, Lake Mummuga, Bodalla	🟨 10.1913706	🟧 184.2648823
NARF2	Part of North Narooma, Narooma, Corunna, Tilba Tilba, Dignams Creek and Mystery Bay	🟥 45.41287794	🟨 98.02130168
BERB2	Beauty Point, Akolele, North Bermagui	🟩 9.104827545	🟩 33.80205315

🟩 🟩 🟨 🟨 🟧 🟧 🟥 🟥

Low High

Image: istock by Getty Images Baracapix

What is a microgrid and how could they improve energy resilience?

In essence, microgrids are small electricity grids.

Microgrids are small

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 connected to other grids with switches that allow them to connect and disconnect to/from these grids. 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 'islanded' 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.

Microgrids are grids

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.

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 power into the upstream grid (or by importing power) to help balance supply and demand in the larger grid. Additionally, the ability of microgrids to operate in islanded mode can be drawn upon in a more planned manner. 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.[10]

Despite making these valuable contributions to resilience, microgrids (and any technologies in general) 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 therefore finite.

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[10] https://www.nrel.gov/docs/fy23osti/80746.pdf

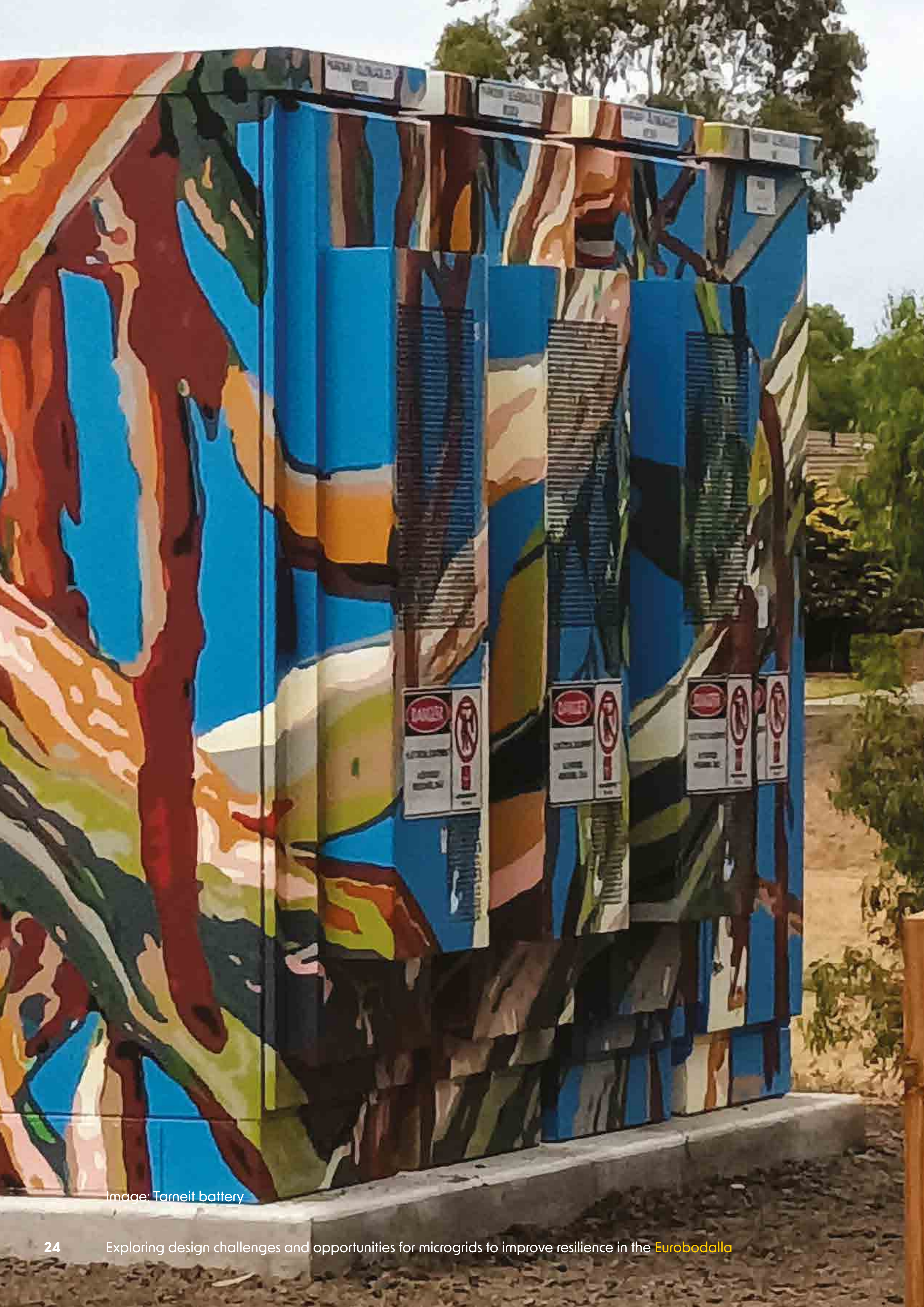

Image: Tarneit battery

What kinds of microgrids could be used in the Eurobodalla?

Since there is no strict definition on the spatial, technological or electrical bounds of microgrids, we devised a set of three microgrid archetypes to examine in the context of the Eurobodalla, together with another (fourth) option: 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).

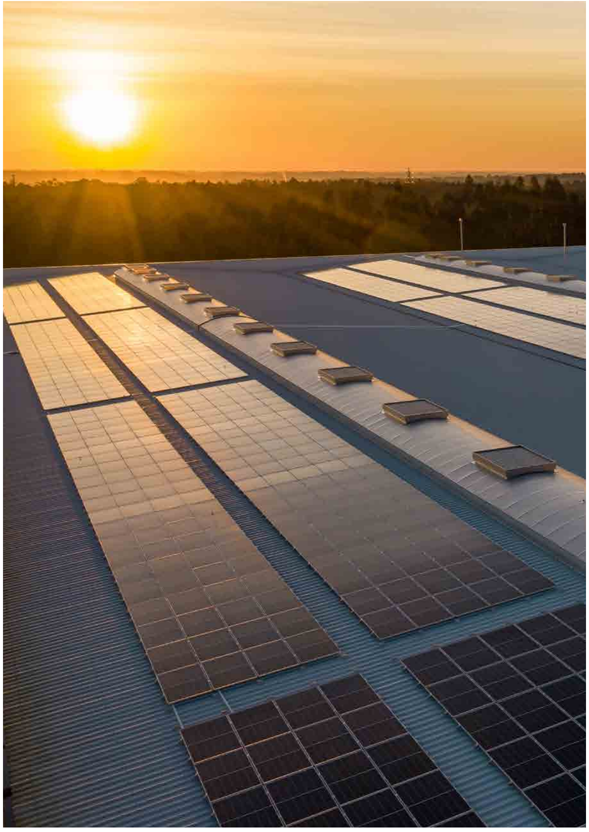

Image: Nuno Marques on Unsplash

The defining features of these 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[11] (Vic) and is being deployed in Bawley and Kioloa[12] (NSW).

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

[12] https://yoursay.endeavourenergy.com.au/bawley-point-kioloa-community-microgrid

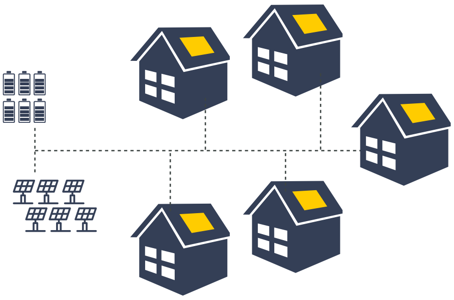
A large solar microgrid

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[13] (SA).

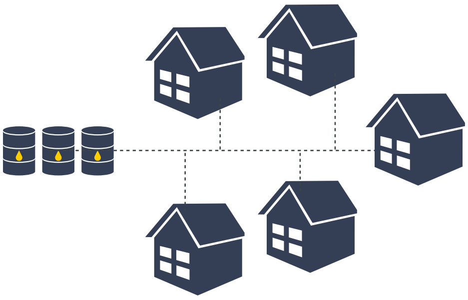


A diesel microgrid

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.



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[13] https://www.electranet.com.au/electranets-battery-storage-project/

Image: Eurobodalla Coast Tourism ©

What sized microgrids could be practical for the Eurobodalla?

In the context of the climate emergency – which is being driven by fossil fuel use – and strong community support for the transition to renewable energy systems, the SµRF project is particularly interested in understanding the potential for solar powered microgrids (models 2, 3 above).

To provide guidance for this exploration, we developed conceptual microgrid designs for each of the eight communities. The microgrid designs specify the amount of solar and the amount of battery storage installed in the community as part of a hypothetical *small solar microgrid* or *large solar microgrid*.

Solar capacities

The design methodology for the small solar microgrids was to set 100% of unshaded roofs in a community to have rooftop solar. This is calculated from the sum of existing solar systems plus an additional 5 kW of solar installed on every additional unshaded roof.[14]

The design methodology for the large solar microgrids was to retain the solar on 100% of unshaded roofs from the small solar microgrid design and add to this a solar farm connected in close proximity to the community. The capacity of the solar farm is set to 4.99 MW – the maximum capacity that can be deployed without requiring formal registration with AEMO as a generator. The solar farm option is only included if we found a sufficiently large amount of cleared land close to the community and to the existing distribution network.

Figures 15, 17 and 19 show examples of communities that, sequentially, have access to sufficient cleared land for a 4.99 MW solar farm, have access to a smaller amount of land, and have no access to cleared land in proximity to the community. Of the eight communities, only Broulee and South Durras were found to have no access to cleared land. We emphasise that this analysis is very simplistic and high-level. It does not consider the terrain of the land, ownership of the land, or planning/development considerations.

To get a more concrete sense of how much land 4.99 MW solar farms would occupy in these landscapes – and to quantify the amount of solar that could be accommodated in smaller cleared areas – we engaged engineers at ITP Renewables to design prospective layouts for each hypothetical site. Example designs are shown in Figure 16 for Tuross Head and Figure 18 for Congo. A full set of drawings for each community are available on our project website.[15]

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[14] Shading was assessed using the APVI SunSpot tool https://solarcalculator.sunspot.org.au/

[15] https://bsgip.com/research/projects/southcoast-%c2%b5-grid-reliability-feasibility-s%c2%b5rf-project/

Figure 15 Cleared land to the NW of Turros Heads provides plentiful space for a 4.99 MW solar farm

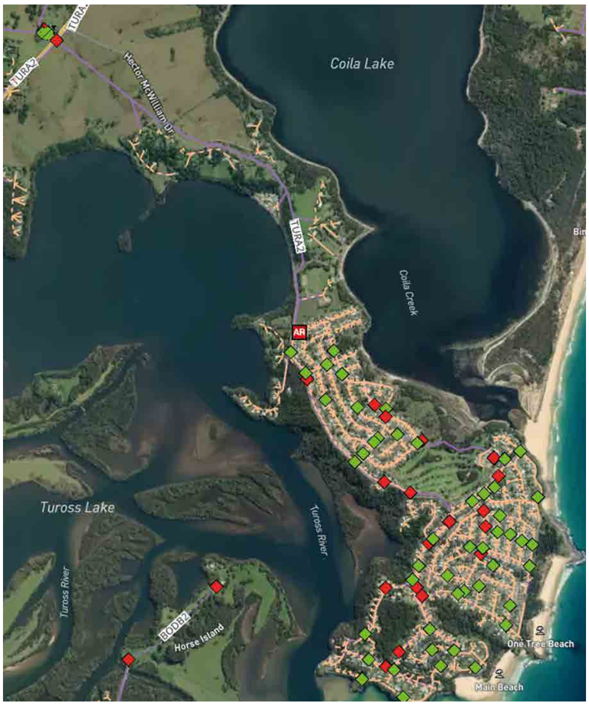

Figure 16 Illustrative design of a 4.99 MW solar farm on the outskirts of the community of Tuross Heads

Figure 17 A cleared patch in the NW of Congo provides space for a 0.98 MW solar farm

Figure 18 Illustrative design of a 0.98 MW solar farm in the community of Congo

Figure 19 The community of Broulee is completely surrounded by forest, leaving no space for a solar farm

Battery capacities

There are two variables for batteries that require specification: the amount of energy that can be stored (measured in units of Watt hours) and the power rate at which energy can be moved into and out of the battery (measured in units of Watts).

In contrast to solar, the size of a potential battery is not constrained by access to physical space. This is because the relevantly sized batteries are much smaller than solar farms. The limitations with batteries are their cost and that they provide a limited source of revenue, as batteries do not generate but rather consume small amounts of electricity through imperfect round trip efficiencies.

To size the batteries in the small solar microgrid, we follow the example set in the Bawley Point Kioloa Microgrid[16] (located immediately to the north of the Eurobodalla) and set the battery power capacity equal to the peak demand of the community and the energy capacity to one hour of peak power consumption. We consider all battery storage capacity to be contained in one battery connected to the distribution network, rather than many batteries installed BTM in properties. Our motivation for this is primarily simplicity, although we also note that BTM batteries open up issues regarding equity and maintenance.[17]

For the large solar microgrid, we set the battery power capacity to 75% of the solar farm power capacity to ensure a high rate of utilisation. As with the sizing of solar, we also constrained the battery power to be less than 4.99 MW to avoid the burdens of AEMO registration.

To set the battery energy capacity we run a range of simulations to assess the length of independent microgrid operation (method described in the following section) and select the smallest energy capacity that achieves near indefinite operating times. An example of such analysis is shown in Figure 20 for the community of Mystery Bay, with corresponding results for the other communities contained in the Appendix.

For batteries there are two variables that require specification:

the amount of energy that can be stored ... and the power rate at which energy can be moved into and out of the battery

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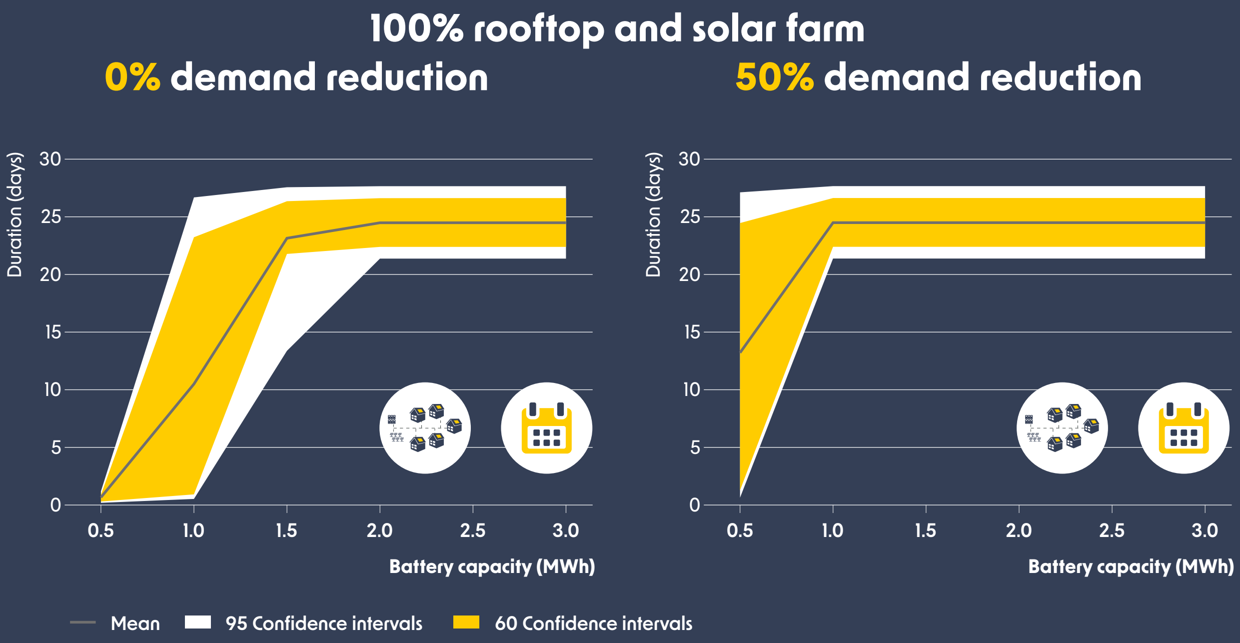
[16] https://yoursay.endeavourenergy.com.au/bawley-point-kioloa-community-microgrid

[17] https://www.sciencedirect.com/science/article/abs/pii/S2214629622000779

Figure 20 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Mystery Bay



100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure 20 illustrates how:

Larger battery energy capacities support longer operating times.

The mean operating time asymptotes (maxes out) at roughly

24 days.

This is an artifact of the simulation method (in which we limit the maximum length of any single scenario) so that values of 24 days can be understood to mean that the microgrid operates effectively indefinitely.

The increase in operating time with battery energy capacity can be quite rapid. This is because sometimes microgrids require only a small extra amount of storage – and operating time – in order to sustain themselves through to the next period of abundant sunshine (and solar generation).

The outputs of our design methodology are summarised in Table 2. Two points stand out. Firstly, Nelligen's large rate of electricity consumption per property flows through to a much larger battery energy capacity (per property) than other communities. This would present a significant extra financial challenge for a business case.

Secondly, our choice of capping the battery power capacity at 4.99MW (to avoid burdensome network connection requirements) means that the batteries in Tuross Head and Bodalla are unable to meet the communities' peak demand – which are 6.9 MW in Tuross Head and 5.5 MW in Bodalla.

Table 2 Summary of the solar and storage capacities specified in the conceptual solar microgrid designs

Community	Peak demand	Small solar microgrid		Large solar microgrid	
		Solar (rooftop)	Storage	Solar (rooftop and solar farm)	Storage
Tuross Head	6.9 MW	8.83 MW	4.99 MW : 4.99 MWh	138 MW	4.99 MW : 200 MWh
Nelligen	1.0 MW	0.72 MW	0.99 MW : 0.99 MWh	1.7 MW	0.99 MW : 4.0 MWh
Bodalla	1.8 MW	1.53 MW	1.80 MW : 1.8 MWh	6.5 MW	3.6 MW : 7.15 MWh
Broulee	5.5 MW	6.34 MW	4.99 MW : 5.5 MWh	-	-
Mystery Bay	0.5 MW	0.43 MW	0.55 MW : 0.55 MWh	5.4 MW	2.0 MW : 2.0 MWh
Congo	0.3 MW	0.55 MW	0.35 MW : 0.35 MWh	1.6 MW	0.75 MW : 1.5 MWh
South Durras	1.2 MW	0.78 MW	1.2 MW : 1.2 MWh	-	-
Central and Tilba Tilba	1.3 MW	0.96 MW	1.3 MW : 1.3 MWh	6.0 kW	2.6 MW : 5.2 MWh

One of the attractions of creating solar powered microgrids that remain connected to the broader grid is that their solar systems produce zero-emissions electricity throughout the year. This is advantageous both to the environment as well as to their business cases

One of the attractions of creating solar powered microgrids that remain connected to the broader grid is that their solar systems produce zero-emissions electricity throughout the year. This is advantageous both to the environment as well as to their business cases.

The impact of the specified solar systems on the carbon emissions of the Eurobodalla communities is quantified in Table 3. This calculation compares each community's current electricity demand with the expected output of the specified solar systems, such that a reduction greater than 100% means that, across a year, the solar systems are producing more electricity than the community is using.

While these numbers show the fantastic potential of solar power, it's important to understand that, even in the presence of large batteries (as specified in the microgrid designs), these communities are still relying on power from the grid. The daily pattern would be for large amounts of solar to be exported into the upstream grid during sunshine hours, and the vast majority of the communities' evening and overnight electricity needs being met from imports of non-solar power from the grid.

Table 3 Impact of the solar systems specified in the conceptual small and large solar microgrid designs on the carbon emissions for the Eurobodalla data set*

Community	**Reduction in carbon emissions**	
	Small solar microgrid	**Large solar microgrid**
Tuross Head	111%	174%
Nelligen	63%	152%
Bodalla	75%	319%
Broulee	101%	-
Mystery Bay	70%	892%
Congo	139%	391%
South Durras	56%	-
Central and Tilba Tilba	65%	400%

* Values greater than 100% indicate where the solar systems are cumulatively generating more electricity over the course of a year than the community consumes.

Network capacity

Having identified that large solar microgrids would generate far more power during the daytime than their local community uses, it raises the question of whether or not the electricity network upstream of these solar farms would be able to accommodate this amount of power flowing back upstream towards the transmission system.

We investigate this issue by reviewing the capacity and loading of the sub-transmission system across the Eurobodalla based on the latest Essential Energy Distributional Annual Planning Report.[18] The first thing that this quantifies is the power rating of the transformers connecting the 33 kV sub-transmission power lines to the 11 kV distribution power lines. It also contains the power ratings of the 33 kV power lines of the sub-transmission network and how much power is consumed at each zone substation (specifically the forecast peak demand).

These numbers are reproduced in Table 4. They show that the peak demand for electricity in each community is very much less than the rating of the transformers and power lines (even when they're de-rated in summer due to heat). For the purposes of solar farms, the low demand numbers suggest that 4.99 MW solar farms may well create reverse power flows through the substation transformers into the 33 kV sub-transmission network, while the transformer and line ratings suggest that the substations and sub-transmission network have spare capacity to accommodate such power flows, except in the Bodalla and Tuross zone substations.

Once the solar power is in the 33 kV sub-transmission network it will flow freely throughout the Eurobodalla. If, however, there were many large solar farms connected in the Eurobodalla, power would eventually flow back through the substation at Moyura North into the 132 kV transmission network. The transformer in this substation may therefore place a constraint on the amount of solar that can be installed across the Eurobodalla (rooftop and solar farm). The rating of this transformer is 44 MVA (Mega Volt Amperes). This is far above any current visions of solar farm development for the Eurobodalla, but is only moderately more than the combined solar capacity of the eight largest microgrids considered in this study (which sum to 36 MW). For another reference point, it is considerably less than the power rating of many solar farms being built in Australia today (100–300 MVA). This raises questions of how this finite resource (of network capacity) might be allocated to communities across the region.

These numbers are reproduced in Table 4. They show that the peak demand for electricity in each community is very much

less than

the rating of the transformers and power lines

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[18] https://dapr.essentialenergy.com.au/essential_data/DAPR_Essential%20Energy_2022_Final.pdf

Table 4 Rating of 33/11 kV zone substation transformers, 33 kV sub-transmission power lines and forecast peak power demand in summer and winter across the zone substations of the Eurobodalla

	Transformer rating	Summer line rating	Forecast 2023 peak summer demand	Winter line rating	Forecast 2023 peak winter demand
Moruya Town zone substation	17.6 MVA	26 MVA	8.7 MVA	30 MVA	11.6 MVA
Mossy Point zone substation	13.75 MVA	25 MVA	5.9 MVA	28 MVA	7.9 MVA
Bodalla zone substation	3.3 MVA	10 MVA	1.2 MVA	19 MVA	1.6 MVA
Tuross zone substation	Unknown	7 MVA	1.7 MVA	12 MVA	2.9 MVA
Narooma zone substation	13.75 MVA	10 MVA	5.5 MVA	19 MVA	7.8 MVA

BTM battery and diesel generator capacities

Lastly, we specify conceptual designs for BTM battery systems (model 1) and diesel generators (model 4) for a specific building (i.e. an emergency shelter or a small supermarket) in Table 5. The design methodology for the BTM batteries is to set their energy capacities equal to half an hour of average community level consumption. This was chosen over a method based on the number of properties in the community so as to capture the different energy needs of communities with large numbers of businesses. The battery power capacity was set to allow all energy to be discharged in an hour. This value is not utilised in the costing of the batteries (or any other analysis).

The diesel generators are sized to match the peak demand of each community, except where this exceeds 5 MW, in which case the capacity is brought down to 4.99 MW to once more avoid AEMO registration requirements.

Table 5 Summary of the conceptual design for the BTM battery and diesel generator systems for the Eurobodalla communities

Community	BTM battery	Diesel microgrid
Tuross Head	500 kW : 500 kWh	4.99 MVA
Nelligen	75 kW : 75 kWh	0.99 MVA
Bodalla	150 kW : 50 kWh	1.88 MVA
Broulee	500 kW : 500 kWh	4.99 MVA
Mystery Bay	50 kW : 50 kWh	0.5 MVA
Congo	30 kW : 30 kWh	0.35 MVA
South Durras	100 kW : 100 kWh	1.2 MVA
Central and Tilba Tilba	100 kW : 100 kWh	1.3 MVA

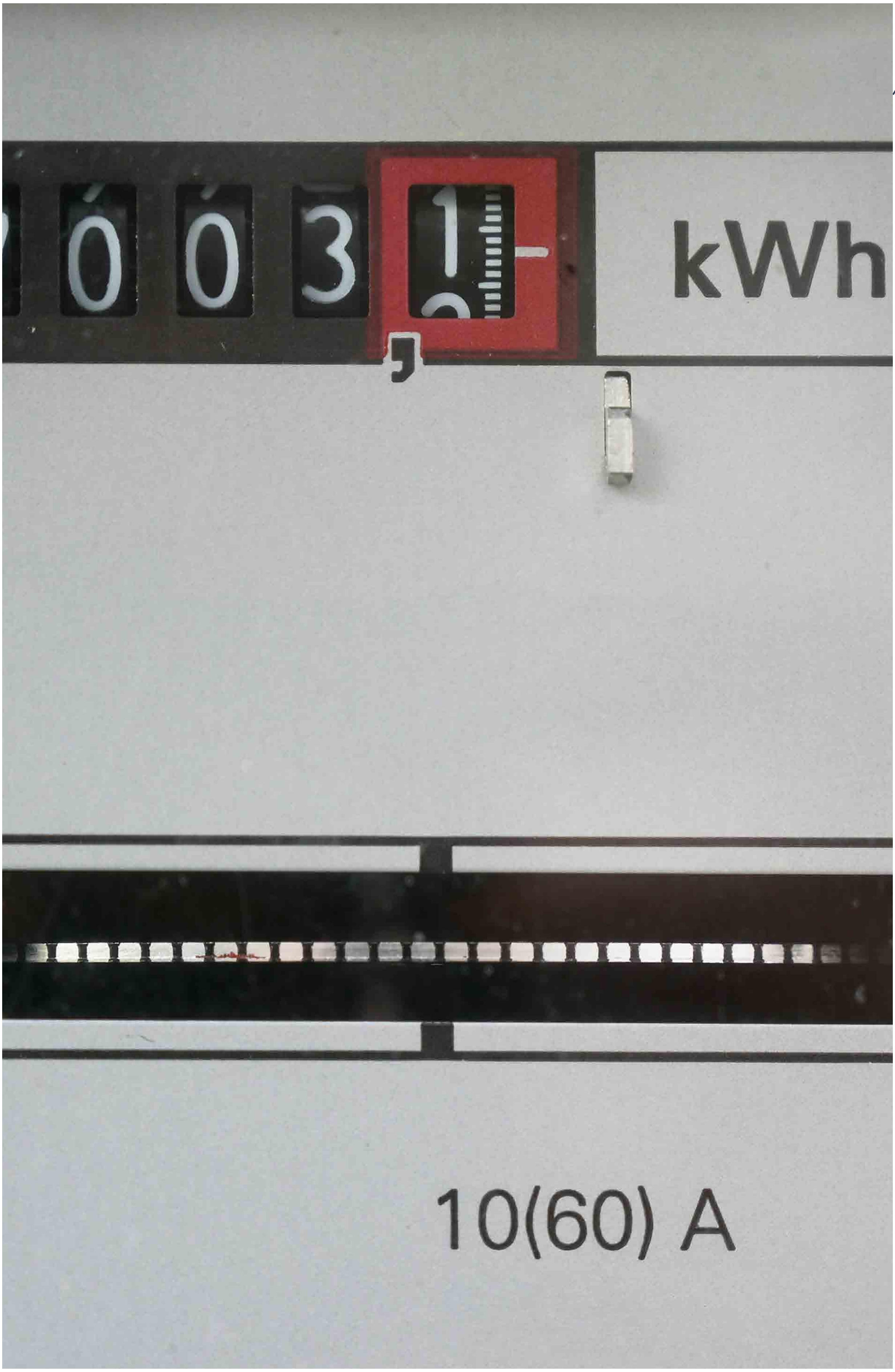


Image: istock by Getty Images fermate

Image: Eurobodalla Coast Tourism ©

For how long could solar powered microgrids operate independently?

Microgrids that rely on solar power and battery storage (models 2 and 3 above) are unlikely to be able to operate self-sufficiently for an indefinite period, as variations in solar generation and customers' electricity use are likely to feature periods of undersupply that deplete the energy storage reserves.

The length of time that a microgrid is likely to be able to operate for before the microgrid shuts down is therefore a key metric for its design and social acceptance.

In this section we approach this question through simulations of the conceptual solar microgrid designs outlined above, across variations in weather and community energy consumption.

Simulation method

Fundamentally, there are three parameters determining the length of independent or 'islanded' microgrid operation. These are the rates of:

1. Electricity consumption
2. Electricity generation, and
3. The capacity of electricity storage.

Electricity consumption and generation are time varying quantities with consumption driven by what appliances are installed throughout a community and the social practices associated with how these appliances are used, while generation is driven by the amount of solar installed throughout a community and the weather. While the use of storage also varies across time, this variation is a response to the mismatches between consumption and generation rather than introducing a new source of variability.

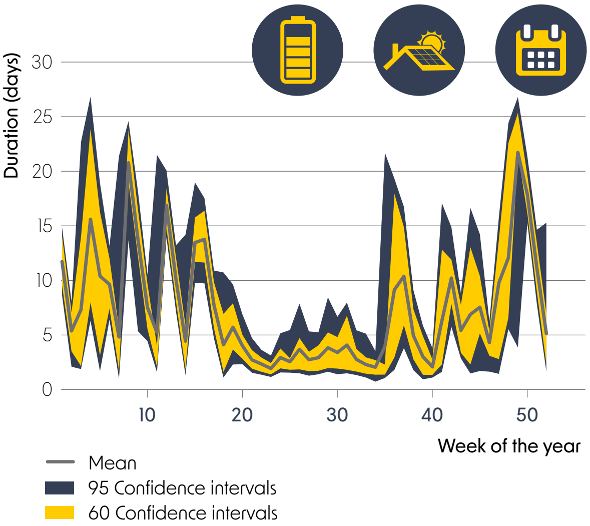
To better understand how long solar microgrids could power the eight Eurobodalla communities we explore the many possible combinations of consumption, generation and storage. We do this using a simulation model that tracks the electricity supply/demand balance of a hypothetical microgrid across time.

For each hypothetical microgrid design we perform a hundred simulations in which the microgrid starts to operate independently at a different time in the year. This sampling across the days of the year and hours of the day is necessary to capture the influence of natural variations in solar generation and customer demand. For example, when microgrids start their islanded operation in the afternoon, they may struggle to last until the next morning because demand is high in the evening while solar generation is waning and then totally absent overnight.

In our model we incorporate these variations by representing each Eurobodalla community as a collection of 100 NextGen properties, each with their own times series of electricity use and rooftop solar generation. To tailor the analysis to a specific community we scale the total load and generation profiles to match the substation level data of average electricity consumption in the relevant community (Table 1).

Figure 21 gives an example of the variation in operating times across a year for a specific microgrid design for the community of Mystery Bay. The figure presents the average (mean) operating time in a grey line together with the 60% and 90% confidence intervals (CI) that quantify the spread in results. The figure demonstrates the impact of both seasonal variations in solar irradiation, with reduced operating times during the middle of the year (winter in Australia), as well as variations due to day-to-day changes in electricity consumption and solar generation, with significant changes in the mean. The observed large spreads in the confidence intervals reflect the influence of the time of day when the microgrid begins independent operation, as well as hour-to-hour changes in solar irradiance.

Figure 21 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for one specific microgrid design* and one electricity consumption scenario** for the community of Mystery Bay



* A small solar microgrid powered by rooftop solar and a 2 MWh battery

** Customers using electricity as per normal

Figure 21...demonstrates the impact of both

seasonal variations

in solar irradiation, with reduced operating times during the middle of the year (winter in Australia), as well as variations due to day-to-day changes in electricity consumption and solar generation...

Electricity use and microgrid design scenarios

With this simulation tool in hand, we can now investigate the effects of varying electricity consumption behaviour and of microgrid design parameters.

Each parameter presents a vast continuum of possibilities, with infinite possible combinations. In the interest of tractability, we focus our analysis on four scenarios for each community. These are made up of the combinations of two scenarios of electricity consumption and two solar generation designs.

Each of these four scenarios is plausible, and collectively they provide reference points from different corners of the parameter space.

The consumption scenarios are:

Regular electricity use

Electricity consumption is set equal to that recorded in the substation data (Table 1).

50% demand reduction

Tests the effect of collective community wide halving of electricity consumption, which was shown to be quite achievable in the chapter 'How is electricity used in the Eurobodlla'. Note that our model simply scales the consumption profiles recorded in the NextGen data to the appropriate cumulative value – it does not alter the shape of the consumption profiles.

The solar and battery system capacities are:

Small solar microgrid

Large solar microgrid

Summary of results for independent operating times

The following presents the results for each of the four scenarios for each of the eight communities. The figures present the variability of operating times across the weeks of the year and a summary of average values. Table 6 summarises the average values for each scenario and community. This highlights how the large community size of Tuross Head and the combination of high per property electricity consumption in Nelligen and limited availability of proximate cleared land limit the operating times of their large solar microgrids.

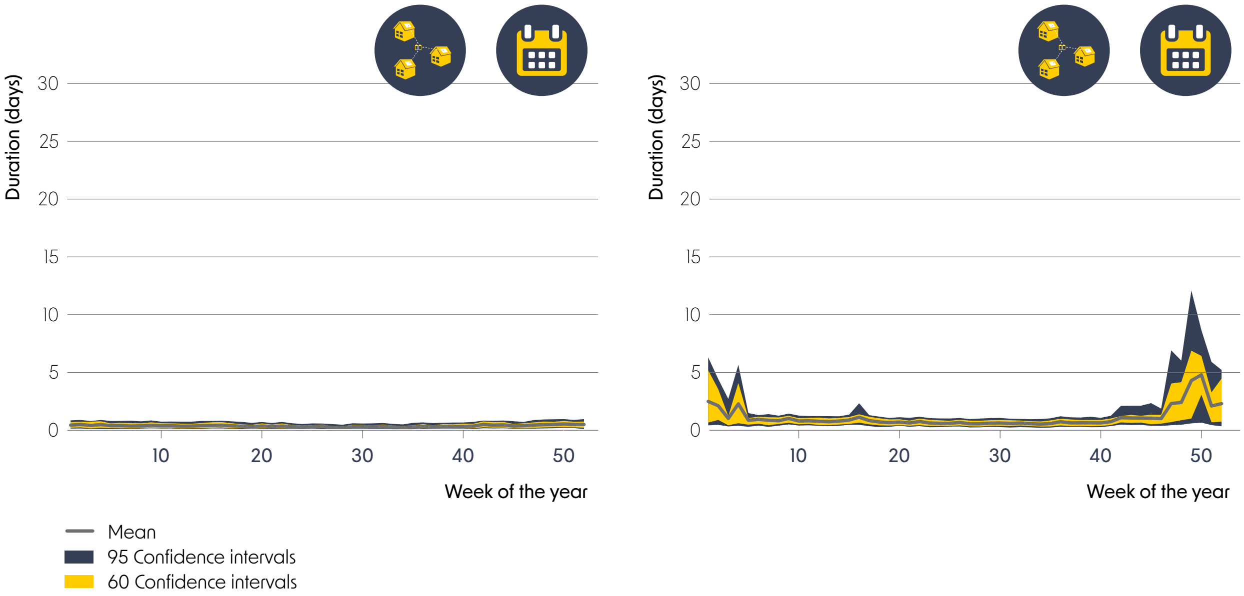
Table 6 Typical length of time that solar microgrids could operate for independently in the eight Eurobodalla communities, averaging across the variabilities of year

Community	Average length of independent ('islanded') operation			
	Small solar microgrid		Large solar microgrid	
	Regular usage	Halved usage	Regular usage	Halved usage
Tuross Head	0.3 days	0.8 days	15.2 days	Indefinitely
Nelligen	0.4 days	1.3 days	22.8 days	Indefinitely
Bodalla	0.4 days	1.4 days	Indefinitely	Indefinitely
Broulee	0.5 days	1.6 days	-	-
Mystery Bay	0.4 days	1.5 days	Indefinitely	Indefinitely
Congo	0.5 days	2.5 days	Indefinitely	Indefinitely
South Durras	0.4 days	1.2 days	-	-
Central and Tilba Tilba	0.4 days	1.2 days	Indefinitely	Indefinitely

Figure 22 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Tuross Head

100% rooftop solar, 5MWh battery*

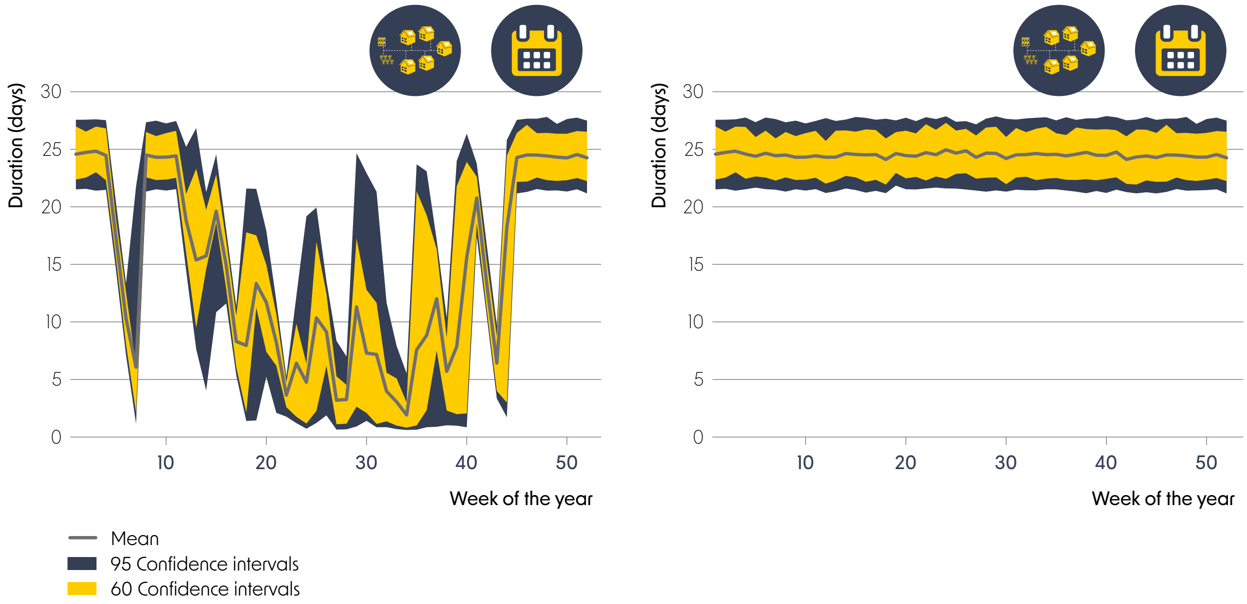
0% demand reduction **50% demand reduction**



* Results for the small solar microgrid (8.83 MW rooftop solar and a 4.99 MW : 4.99 MWh battery)

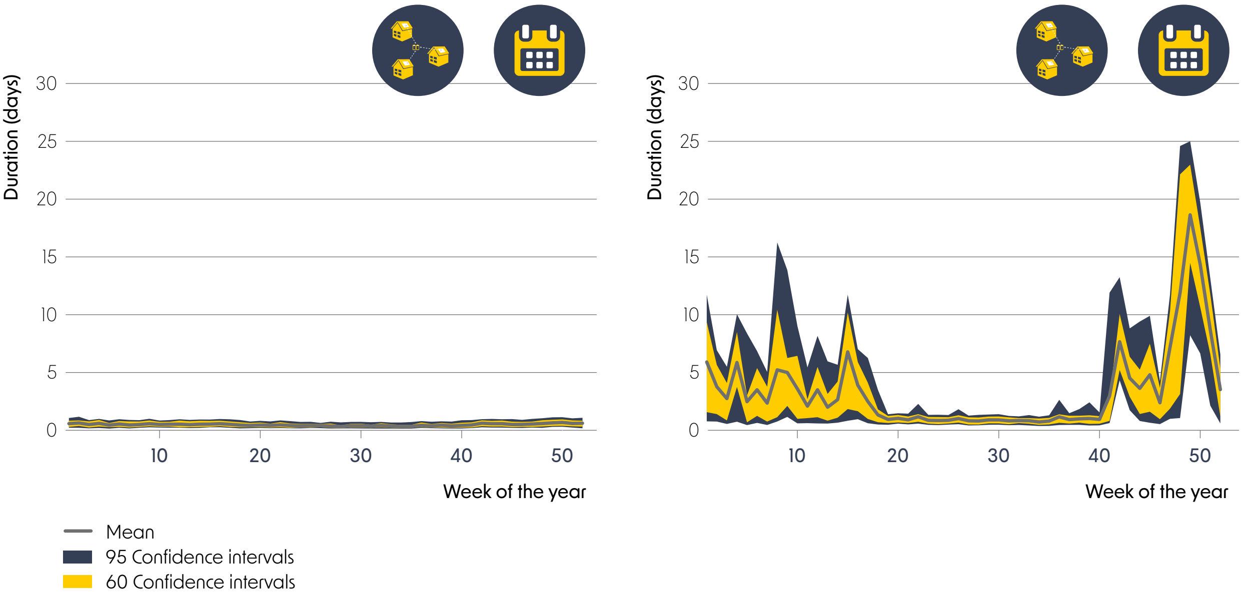
100% rooftop and solar farm 20MWh battery**

0% demand reduction **50% demand reduction**



** Results for the large solar microgrid (13.8 MW of solar and a 4.99 MW : 20 MWh battery)

Figure 23 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Nelligen

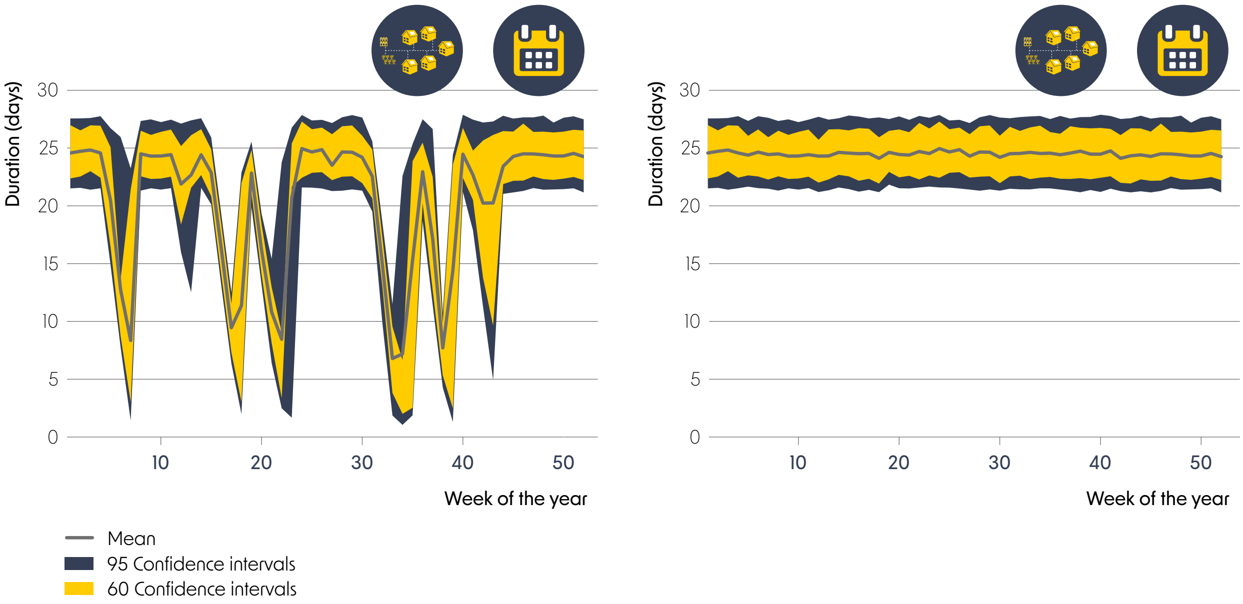


100% rooftop solar, 1MWh battery*

0% demand reduction

50% demand reduction

* Results for the small solar microgrid (0.72 MW rooftop solar and a 0.99 MW : 0.99 MWh battery)



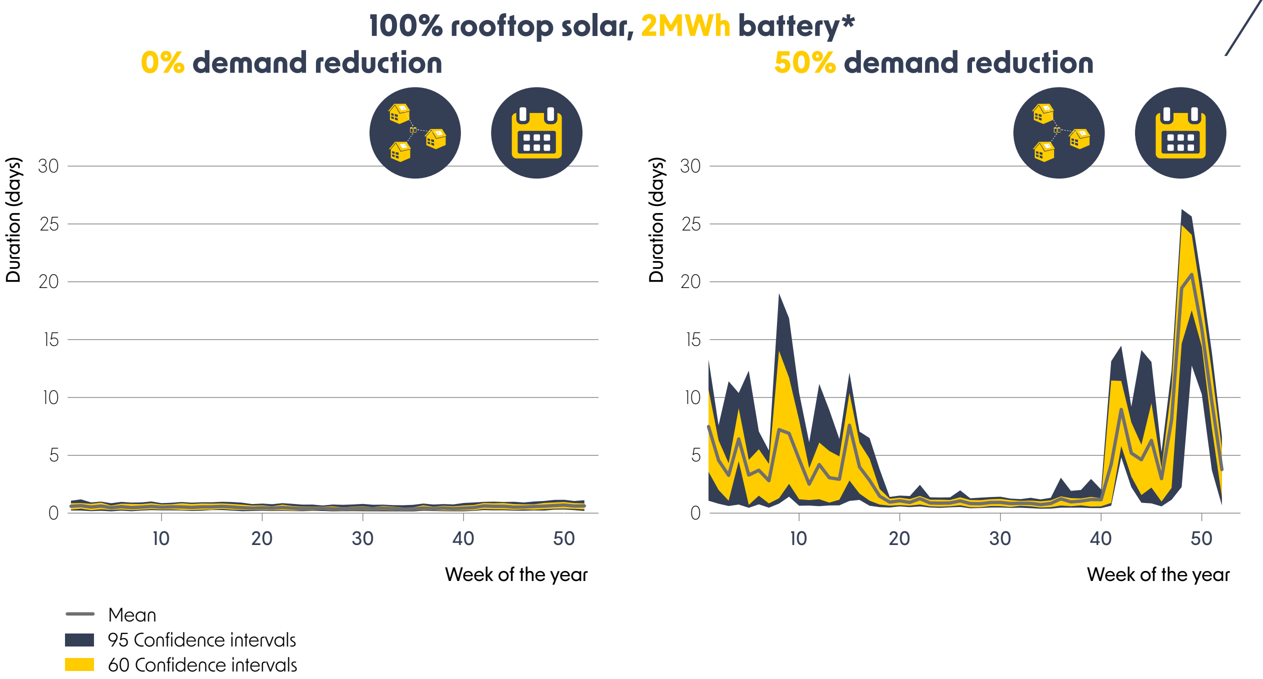
100% rooftop and solar farm 20MWh battery**

0% demand reduction

50% demand reduction

** Results for the large solar microgrid (1.7 MW of solar and a 0.99 MW : 4.0 MWh battery

Figure 24 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Bodalla

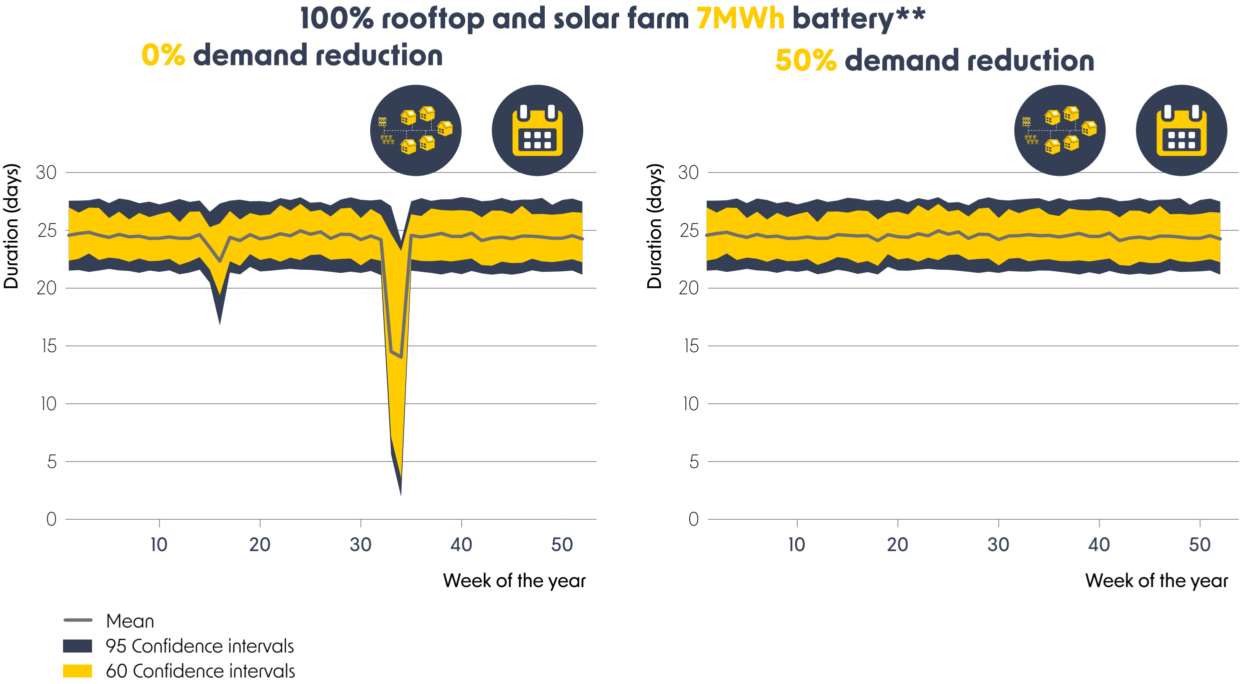


100% rooftop solar, 2MWh battery*

0% demand reduction

50% demand reduction

* Results for the small solar microgrid (1.53 MW rooftop solar and a 1.8 MW : 1.8 MWh battery)



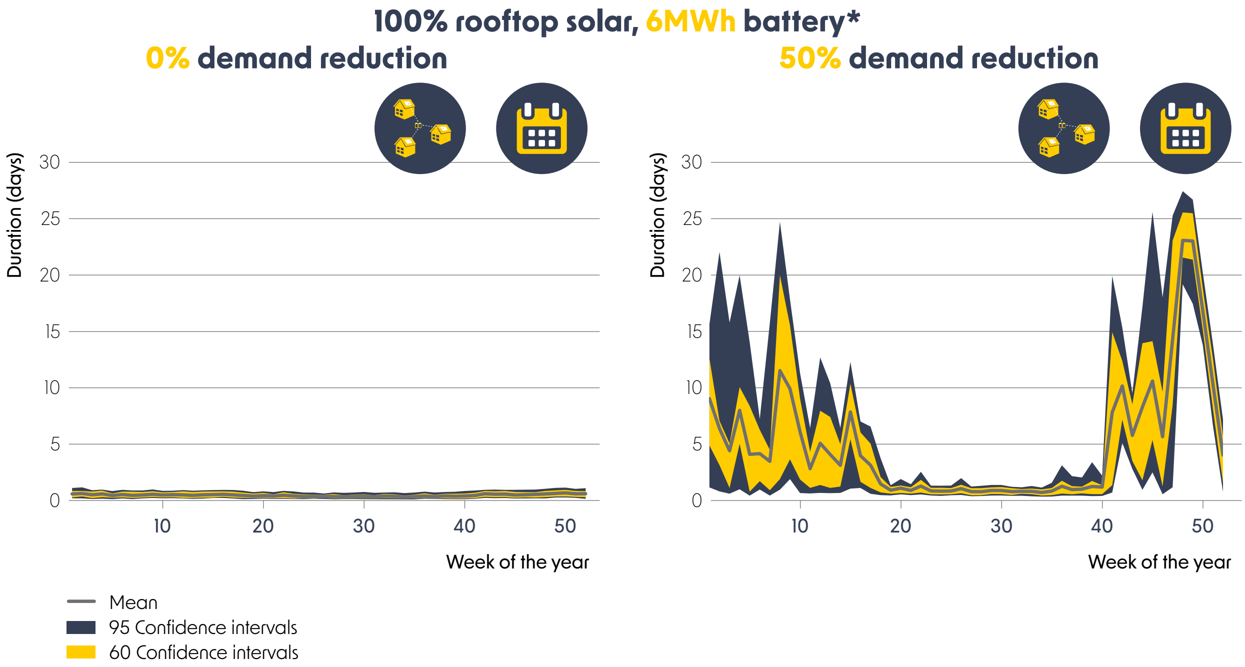
100% rooftop and solar farm 7MWh battery**

0% demand reduction

50% demand reduction

** Results for the large solar microgrid (6.5 MW of solar and a 3.6 MW : 7.15 MWh battery)

Figure 25 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for a small solar microgrid in Broulee



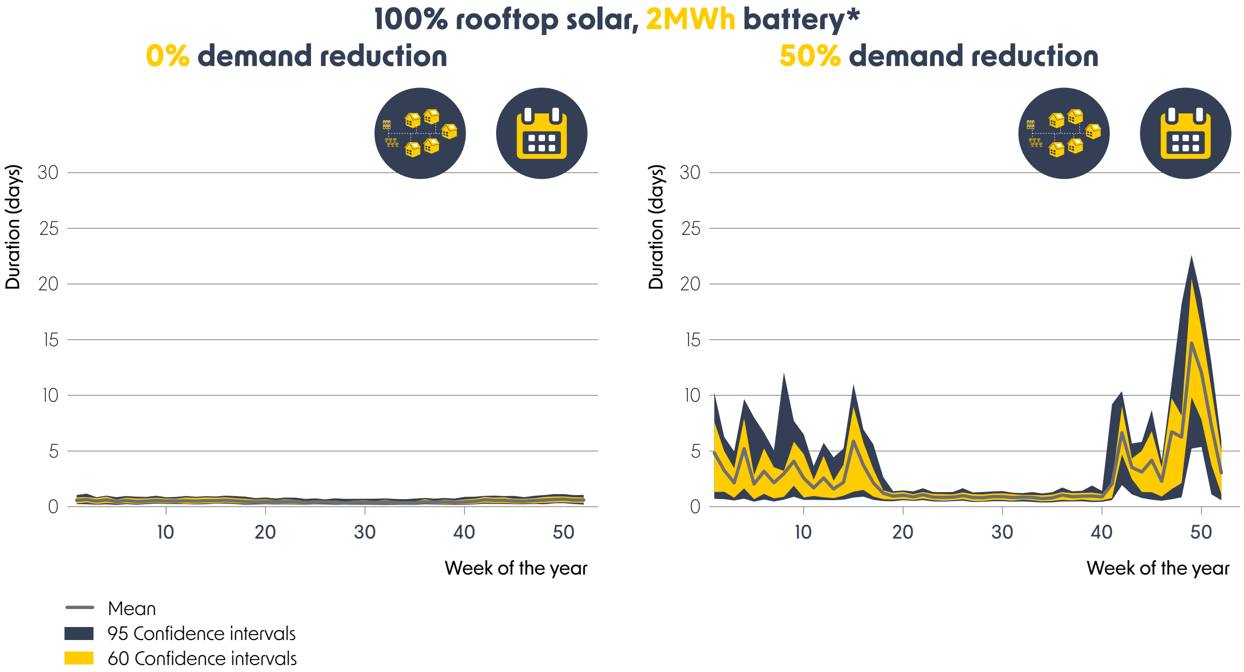
100% rooftop solar, 6MWh battery*

0% demand reduction

50% demand reduction

* 6.34 MW rooftop solar and a 4.99 MW : 5.5 MWh battery

Figure 26 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for a small solar microgrid in South Durras



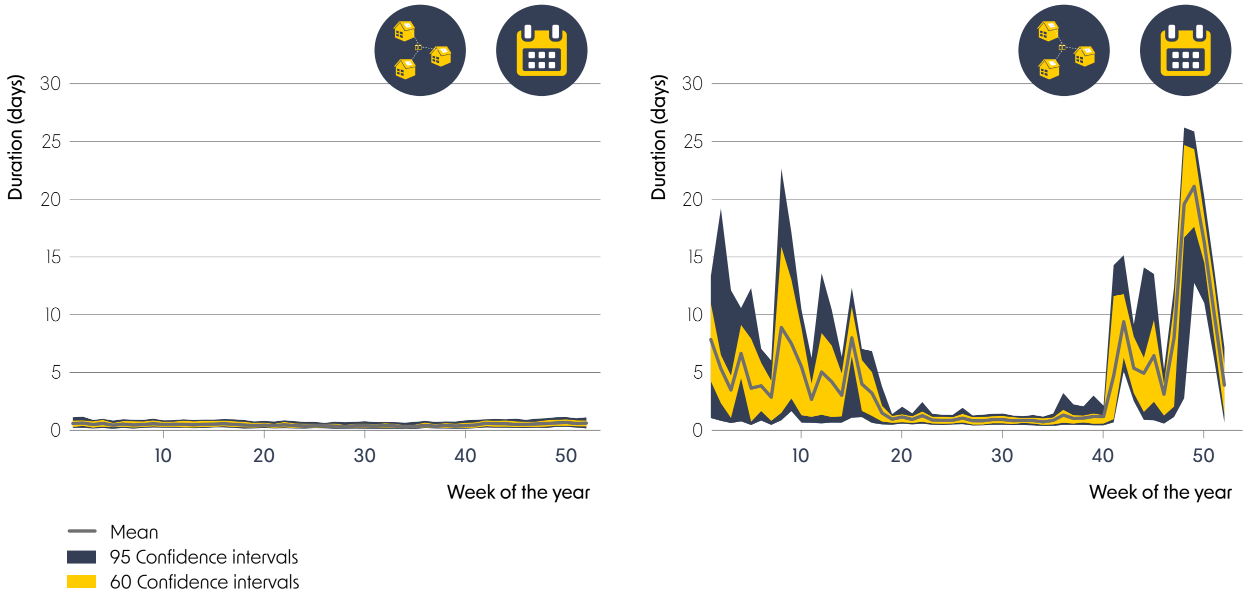
100% rooftop solar, 2MWh battery*

0% demand reduction

50% demand reduction

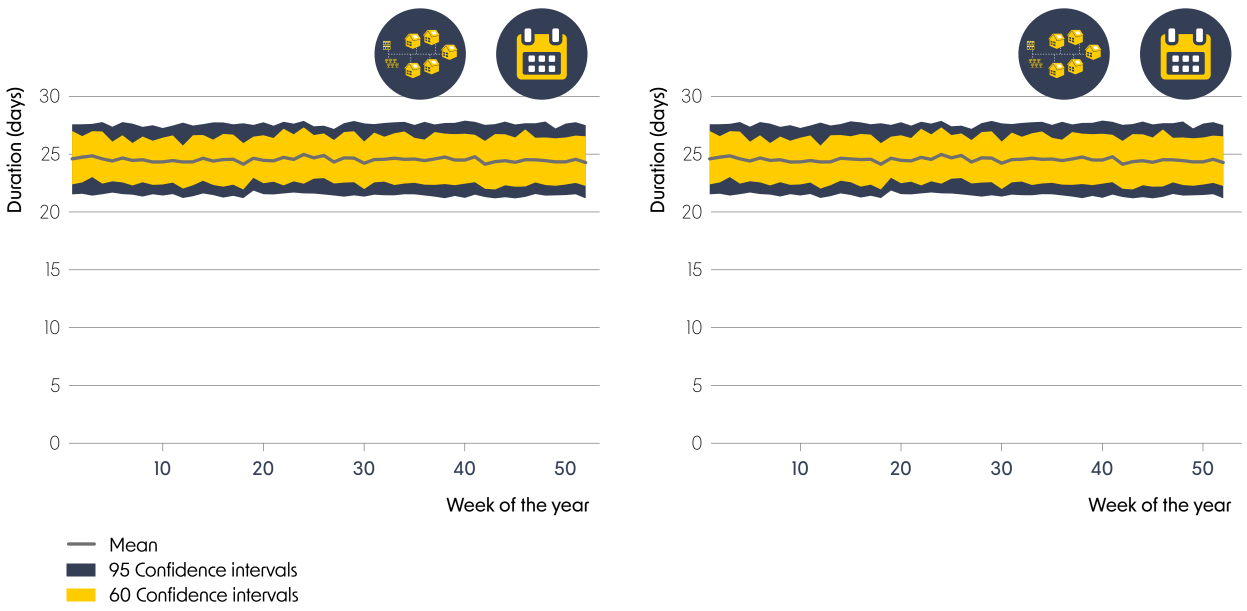
* 0.78 MW rooftop solar and a 1.2 MW : 1.2 MWh battery

Figure 27 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Mystery Bay



100% rooftop solar, 1MWh battery*

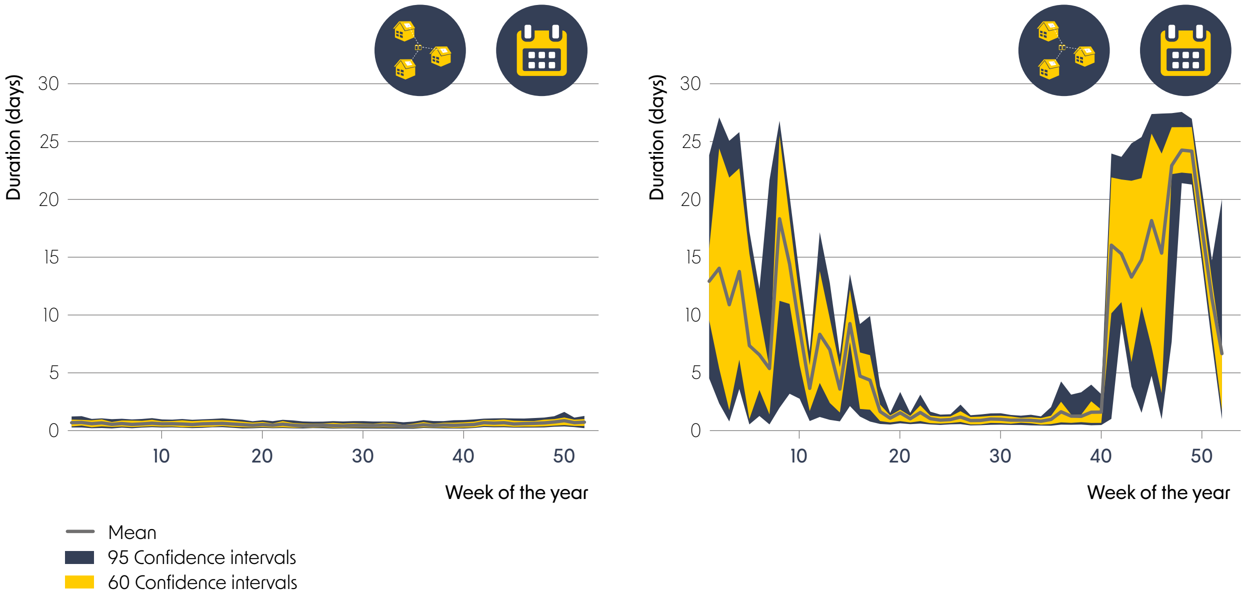
* Results for the small solar microgrid (0.43 MW rooftop solar and a 0.55 MW : 0.55 MWh battery)



100% rooftop and solar farm 2MWh battery**

** Results for the large solar microgrid (5.4 MW of solar and a 2.0 MW : 2.0 MWh battery

Figure 28 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Congo

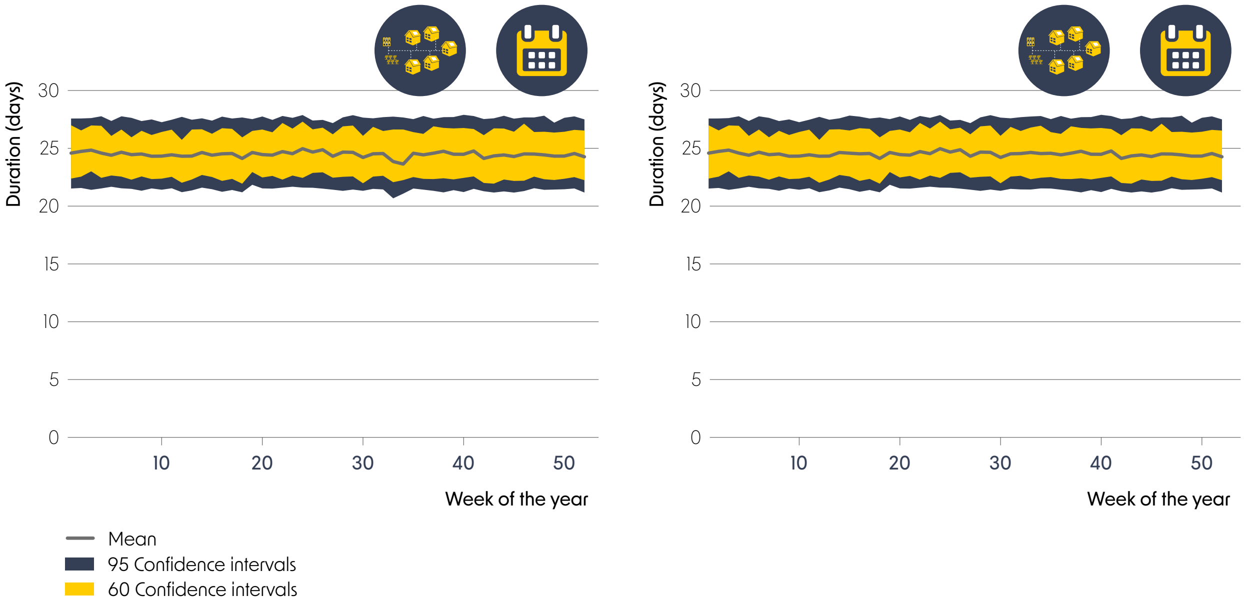


100% rooftop solar, 0.3MWh battery*

0% demand reduction

50% demand reduction

* Results for the small solar microgrid (0.55 MW rooftop solar and a 0.35 MW : 0.35 MWh battery)



100% rooftop and solar farm 1.5MWh battery**

0% demand reduction

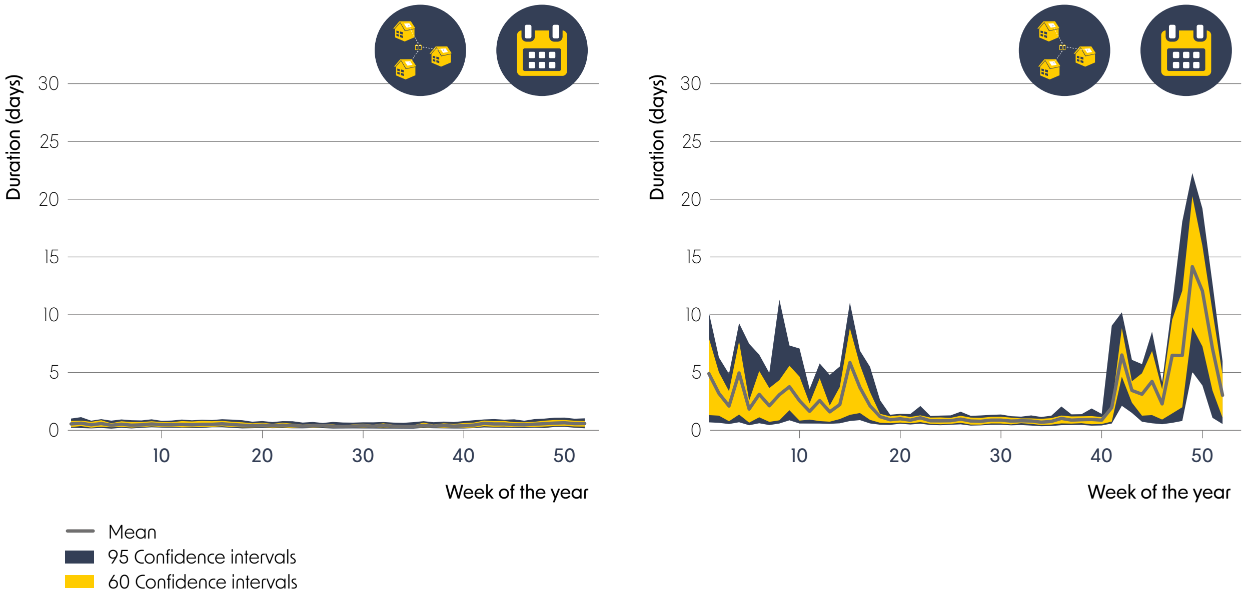
50% demand reduction

** Results for the large solar microgrid (1.6 MW of solar and a 0.75 MW : 1.5 MWh battery

Figure 29 Duration of independent ('islanded') microgrid operation as a function of the weeks of the year for solar microgrids in Central and Tilba Tilba

100% rooftop solar, 1300MWh battery*

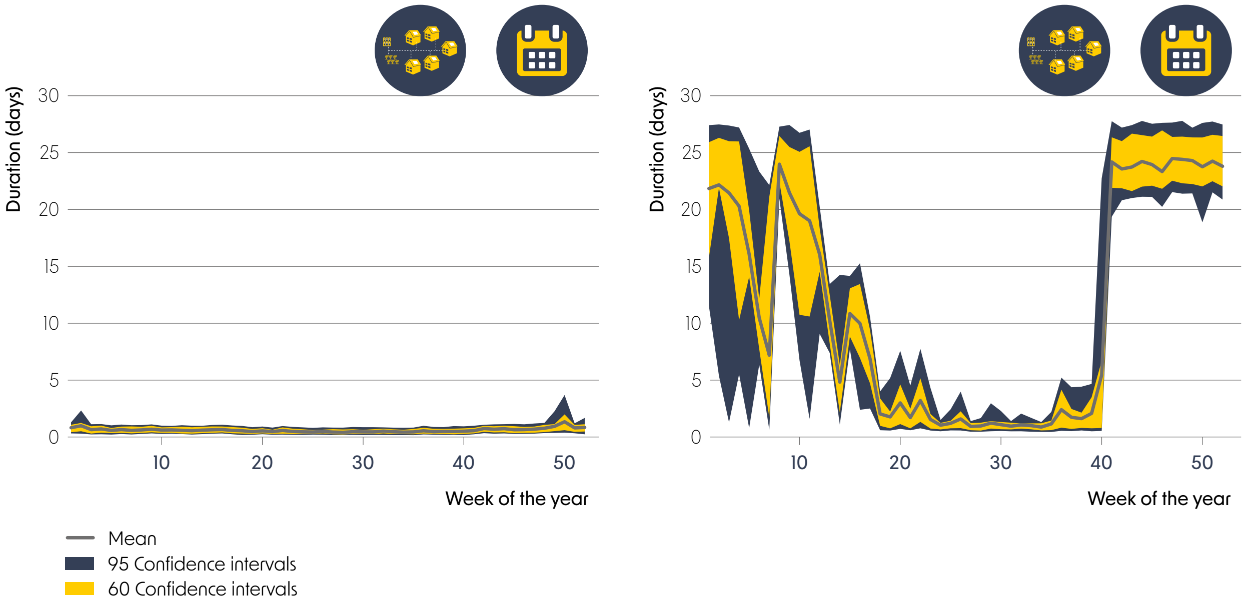
0% demand reduction **50% demand reduction**



* Results results for the small solar microgrid (0.96 MW rooftop solar and a 1.3 MW : 1.3 MWh battery)

100% rooftop and solar farm 1300MWh battery**

0% demand reduction **50% demand reduction**



** Results for the large solar microgrid (6 MW of solar and a 2.6 MW : 5.2 MWh battery)

Image: Eurobodalla Coast Tourism ©

What are the costs of SµRF microgrid designs?

Our development of high-level conceptual microgrid designs for the eight Eurobodalla communities allows us to compose some estimates for their costs.

These costings come with three important caveats. Firstly, they relate to a small number of specific microgrid models (BTM battery, small solar microgrid, large solar microgrid, and diesel microgrid) and designs thereof, chosen from a huge and diverse continuum of possible energy arrangements. These costs (and designs) can only be seen as point samples from these continuums.

Secondly, the cost of rooftop solar is considered to be a cost for property owners and is therefore excluded from the following figures. As a reference point, rooftop solar systems typically cost between $1,400 and $1,600 per kW.

Thirdly, the process of developing and deploying a microgrid involves more than engineering work and asset procurement. Community engagement and business model development will, for example, require extensive time and resources. Land acquisition is multi-faceted and expensive. The scope and structure of these activities may vary widely, and are outside of the scope of this report and not included in the following cost estimates.

With these caveats in mind, table 7 presents the capital costs of developing and deploying each of the microgrid models in the eight Eurobodalla communities. These costs are made up of five components:

1. Development works
2. Engineering, procurement, and construction (EPC)
3. Design and construction principal
4. EPC design
5. EPC margin and contingency

Table 8 presents estimates for the annual operating costs of the microgrids. These are comprised of four components:

1. Management and administration
2. Site operation and maintenance works
3. Insurance
4. Energy brokerage

For more detailed numbers of constituent costs see the accompanying 'Concept Design Report'[19] prepared by ITP Renewables.

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[19] https://bsgip.com/research/projects/southcoast-%c2%b5-grid-reliability-feasibility-s%c2%b5rf-project/

Table 7 Costs of deploying each of the illustrative microgrid designs into each of the Eurobodalla communities

Community	**Deployment cost ($AUD)**			
	BTM battery	**Small solar microgrid**	**Large solar microgrid**	**Diesel microgrid**
Tuross Head	500k	5.3m	18.6m	2.9m
Nelligen	75k	1.9m	7.6m	1.3m
Bodalla	150k	2.4m	18.8m	1.5m
Broulee	500k	5.5m	-	2.7m
Mystery Bay	50k	2.4m	15.3m	0.9m
Congo	30k	1.7m	6.6m	0.8m
South Durras	100k	2.8m	-	1.3m
Central and Tilba Tilba	100k	2.9m	17.4m	1.3m

Table 8 Annual costs of operating each of the illustrative microgrid models in each of the Eurobodalla communities.

Community	**Deployment cost ($AUD)**			
	BTM battery	**Small solar microgrid**	**Large solar microgrid**	**Diesel microgrid**
Tuross Head	0	80k	213k	30k
Nelligen	0	26k	77k	8k
Bodalla	0	35k	207k	13k
Broulee	0	85k	-	30k
Mystery Bay	0	27k	156k	6k
Congo	0	23k	62k	5k
South Durras	0	28k	-	10k
Central and Tilba Tilba	0	29k	186k	10k

Conclusion

Microgrids, of various shapes and sizes, may present appealing benefits to communities across regional Australia, such as bolstered resilience and/or increased utilisation of renewable energy sources.

The degrees to which microgrids can deliver such benefits depends on many factors, and must be weighed up against unresolved issues of affordability, accessibility, and microgrid governance. This report focussed on the design challenges and opportunities for microgrids to improve resilience in the Eurobodalla region of the South Coast of NSW. Community expectations, and operational and business model considerations are covered in other project reports.

We examined the technical requirements of microgrids in the Eurobodalla in four broad parts:

1. Quantifying the way in which electricity is currently used and supplied across the eight Eurobodalla communities selected for this study.
2. Developing 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.
3. Creating high-level conceptual designs or small and large solar microgrids for eight communities across the Eurobodalla and assessing the length of time for which they could independently supply electricity (in what is called 'islanded' mode).
4. Compiling cost estimates for each of the microgrid models in the eight communities.

Considering multiple microgrid models in a variety of communities generated (quite intentionally) a kaleidoscope of hypothetical energy systems. These reflect the breadth of opportunities for evolving the energy systems of regional Australia – which is the overarching goal of the SμRF project. Taken collectively, the set of hypotheticals presented in this report suggests four key pointers for future development.

Generating solar electricity and its consumption

Firstly, in all of the considered (eight) communities there is sufficient unshaded roof space to generate enough solar electricity to cover a large portion of the communities' current electricity use.

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. However, were a community as a whole able to halve its electricity use during times where the microgrid is operating independently, 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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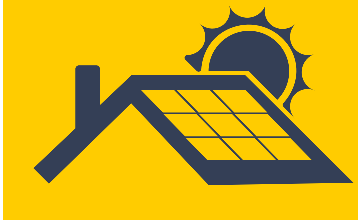

This highlights the fundamental importance of community member's electricity consumption. The analysis of electricity use in properties across the Eurobodalla indicates that reducing electricity consumption by half during an emergency scenario is well within the realms of feasibility, being equivalent to switching off electric hot water systems and air conditioners – for those properties who have these appliances. However, it should be noted that some household types – e.g. families with young children and the elderly may not be able to go without these appliances for health reasons.

The incorporation of energy efficiency upgrades as part of any energy system upgrades would contribute towards demand reduction – and ought to be a corner stone of any energy system evolution.

In contrast, the move to 'electrify everything' will increase demand for electricity and make the resilient supply of electricity even more critical. The electrification of vehicles will have the largest impact, both in terms of potentially doubling household electricity consumption, and in resilience implications of mobility, to evacuate or defend properties. This will need to be factored in to any specific future microgrid proposals.

With the addition of a solar farm

Secondly, where communities are able to accommodate a 4.99 MW solar farm close to town, these solar farms are generally able to power the community indefinitely in independent operation – in the presence of a large (but realistic) battery.

This result hinges on the small size of most of the communities we considered; for the largest community of Tuross Head a 4.99 MW solar farm is insufficient to balance community electricity consumption. This type of microgrid (with a large solar farm and battery) is similar to the arrangement in the Dalrymple microgrid [20] in South Australia that uses a battery and wind farm to power the communities when the microgrid is disconnected from the upstream grid.

A major issue for large solar microgrids in regional Australia is that the business case of the solar farm rests primarily on exporting power to the national market (with the benefits of a microgrid for the local community being a secondary factor). However, the existing distribution and sub-transmission electricity networks have not been built with this purpose in mind. The capacities of existing infrastructure, including power lines and transformers, place constraints on the amount of generation (i.e. solar on roofs and in solar farms) that can be connected in a given region (without requiring network upgrades that are prohibitively expensive for an individual solar farm to pay).

Secondly, where communities are able to accommodate a

4.99 MW

solar farm close to town... they are generally able to power the community indefinitely in independent operation – in the presence of a large (but realistic) battery.

In the Eurobodalla, there appears to be significant spare capacity in existing transformer and line ratings to accommodate significant amounts of solar generation and exports into the sub-transmission network, except in the Bodalla and Tuross zone substations.

For the region as a whole, a single transformer in Moyura places a limit (of 44 MVA) on the amount of power that could be exported into the (132 kV) transmission network. While this is far above any current visions of solar farm development for the Eurobodalla, it is considerably less than the power rating of many solar farms being built in Australia today (100–300 MVA).

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[20] https://www.electranet.com.au/electranets-battery-storage-project/

Impact of natural disasters

Thirdly, an issue that is only beginning to be studied, but which needs to be factored into conceptions of solar powered microgrids, is the reduction of solar irradiance[21] during natural disasters – from rain clouds or bushfire smoke.

One study of the 2019–20 Black Summer fires[22] ffound that solar generation during the fires was generally better than solar generation during winter. Furthermore, the occurrences of consecutive days of low solar generation were less frequent during the fires than during winter. This suggests that microgrids designed to operate year-round may operate reasonably well during natural disasters, however this will depend on the specific weather conditions and microgrid capabilities. This risk bolsters the case for diesel generator powered microgrids.

...the analysis has surfaced a number of issues for consideration about the feasibility and desirability of microgrids, particularly in relation to resilience.

Electricity from diesel

The fourth key finding is that diesel generators are by far the cheapest systems to deploy. They would however produce significant pollution if used routinely or they would provide limited benefits, if used only during rare grid outages.

Moving forward

Ultimately, the outcome of this study is not to dictate a specific a preferred choice of microgrid design, or even whether microgrids are suitable for the Eurobodalla or regional Australia. Rather, the analysis has surfaced a number of issues for consideration about the feasibility and desirability of microgrids, particularly in relation to resilience.

The analysis has provided important inputs into other SμRF project activities and outputs include the individual business and implementation plans for the eight communities. More broadly, these issues will need to be to be weighed up in any deliberations of how microgrids may feature in the evolution of the energy system to be resilient to the stresses of, and compatible with mitigating further worsening of, climate change.

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[21] https://en.wikipedia.org/wiki/Solar_irradiance

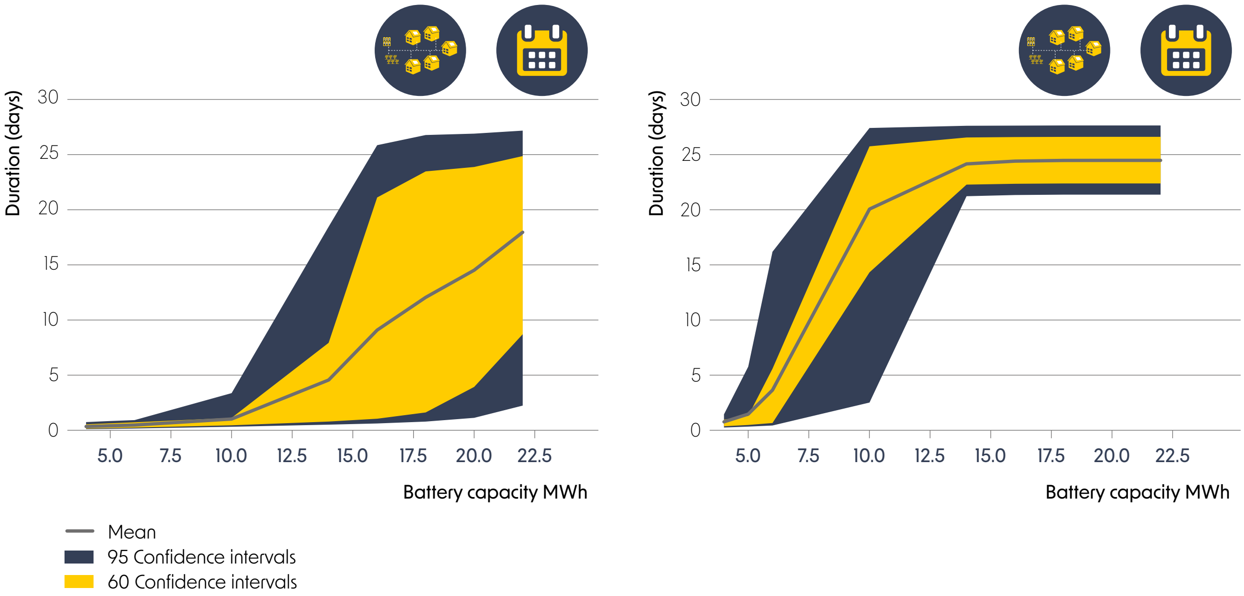
[22] ttps://energy-resilience.com.au/wp-content/uploads/2023/08/ESKIES-Report-2023-08-17.pdf

Appendix: Analysis of battery energy capacity for large solar microgrids

Here we provide simulation results for the length of time for which the large solar microgrids can operate independently for each of the eight communities as a function of the installed battery capacity and across the weeks of the year under regular electricity consumption and reduced consumption scenarios.

Image: chelsea-Wvus on Unsplash

Figure A1 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Tuross Head.

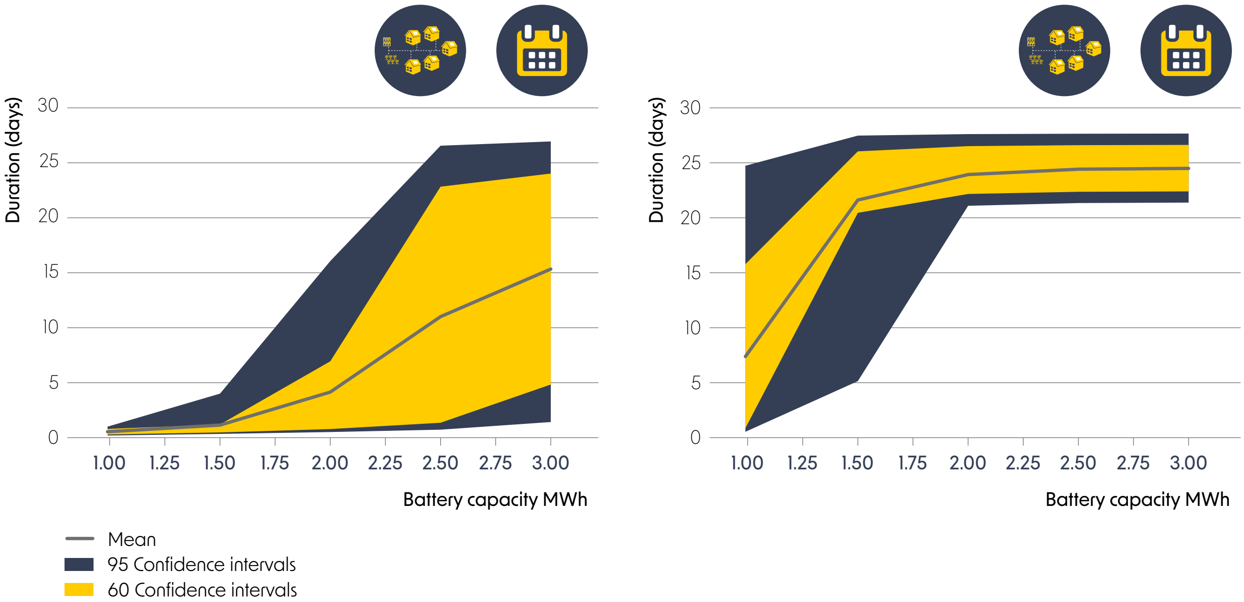


100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure A2 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Nelligen.

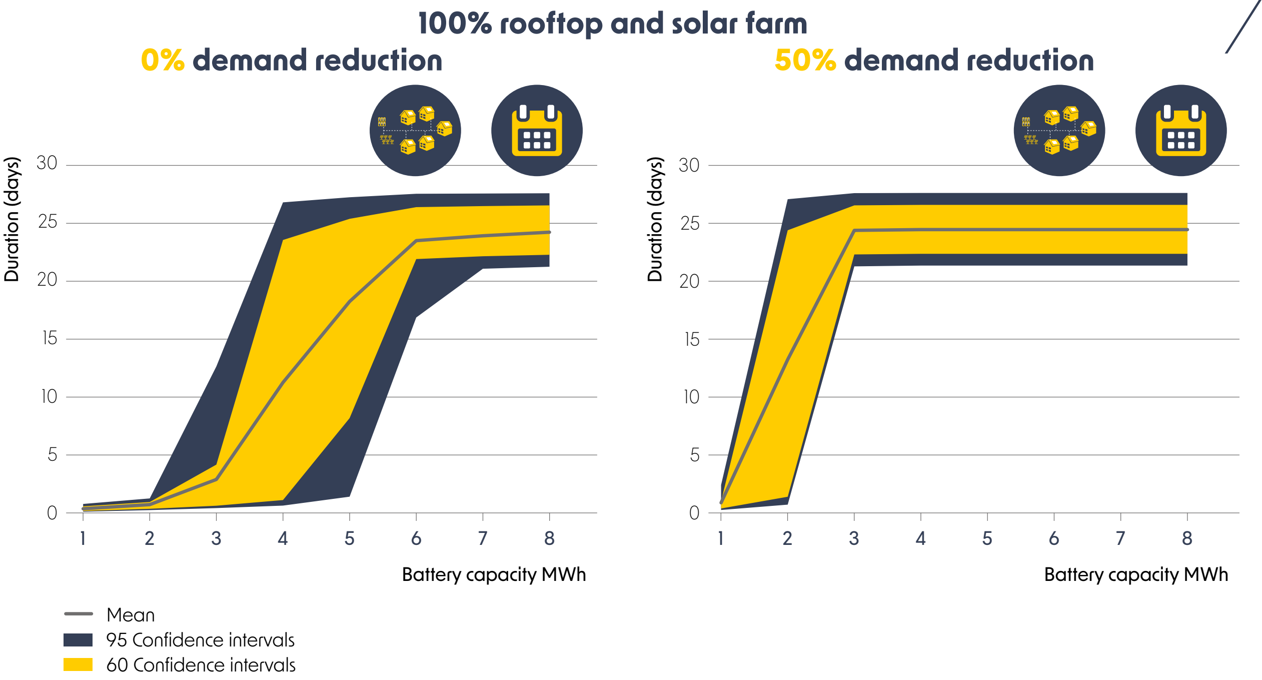


100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure A3 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Bodalla.

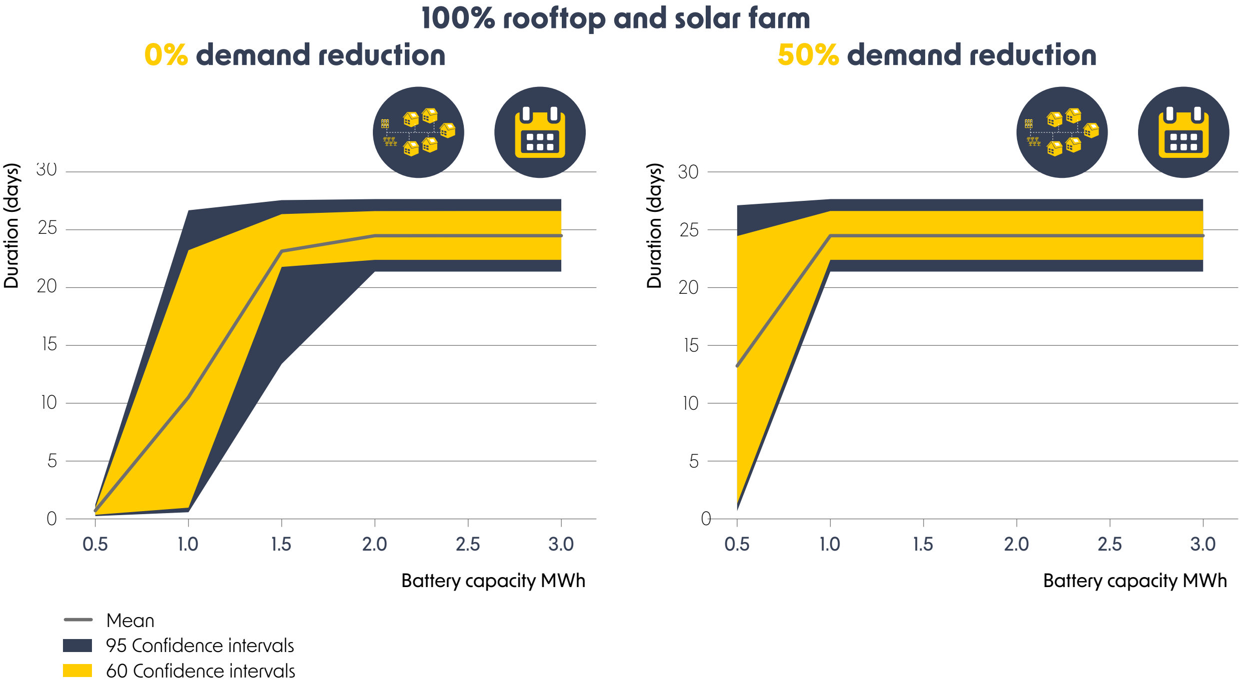


100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure A4 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Mystery Bay.

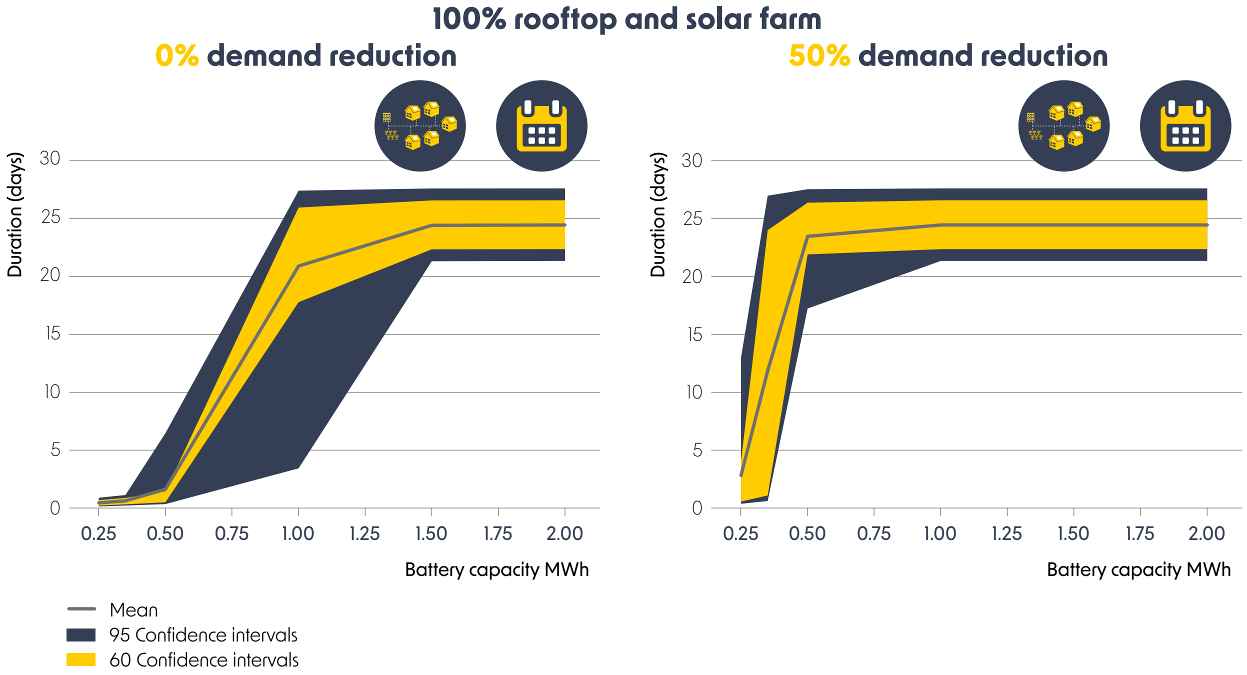


100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure A5 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Congo.

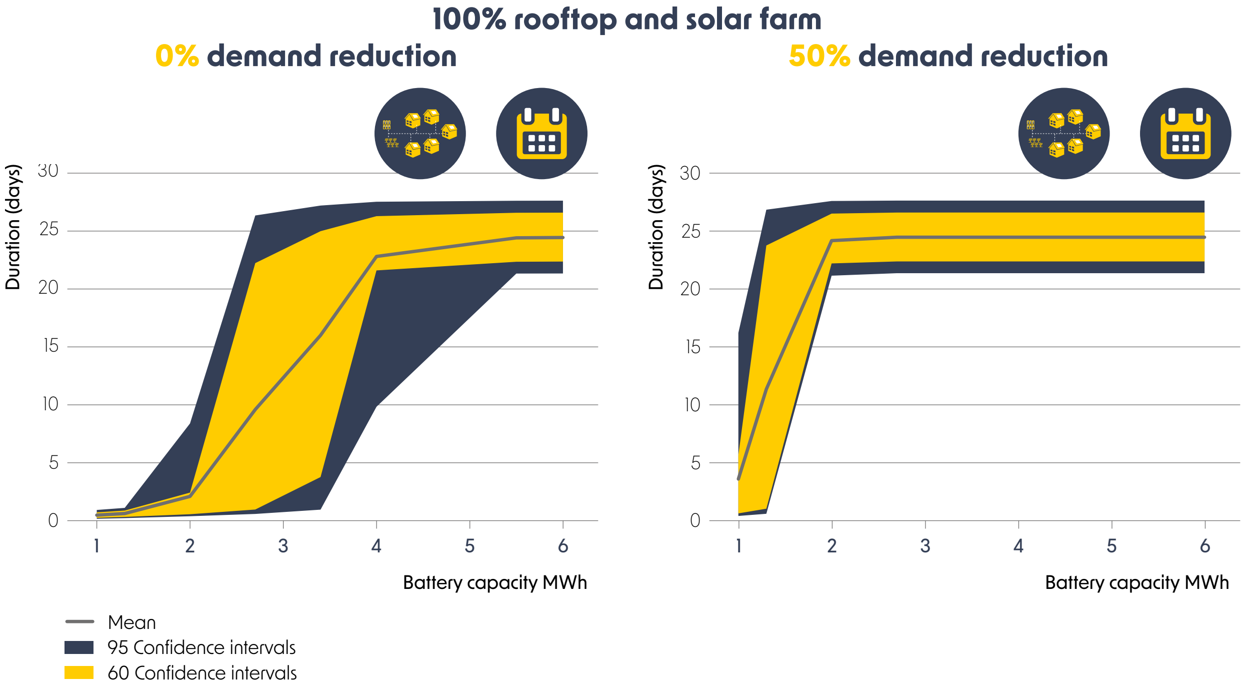


100% rooftop and solar farm

0% demand reduction

50% demand reduction

Figure A6 Length of time of independent microgrid operation for large solar microgrids with varying amounts of battery energy capacity (MWh) for the community of Central and Tilba Tilba



100% rooftop and solar farm

0% demand reduction

50% demand reduction