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Community-scale Batteries in Aotearoa

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Climate Connect Aotearoa

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1 AN OVERVIEW OF COMMUNITY BATTERIES

1.1 WHAT IS A COMMUNITY BATTERY?

A community-scale battery, or neighbourhood battery, consists of a mid-sized battery (usually in the range from 100kWh to 1MWh) embedded in the electricity network. It may have a dedicated connection "in front of the meter" in the local electricity distribution network in a neighbourhood or be located "behind the meter" at an industrial or commercial site.

For over a hundred years, the power system has operated as a one-way system – sending energy hundreds of kilometres from large power plants to neighbourhood homes and businesses. Distributed solar PV systems now make it possible to generate electricity on-site, and feed energy back into the grid. However, too much solar export can cause network stability issues, put pressure on wholesale markets, cause price volatility, and increase operational risk.

In 2023, over one third of Australian households had rooftop solar installations[1]. This is equivalent to over 2.5 million installations and 20GW of installed capacity across Australia[2]. By contrast, only approximately 1.5% (or ~150,000[3]) of Australian households had battery storage. One third of these installations were installed in 2023, indicating a rapid increase in storage penetration.

In 2022, Australian federal and state governments committed $300 million in Australian Renewable Energy Agency (ARENA) funding to support various neighbourhood battery projects and initiatives across the country[4]. In some trials, households have been allocated a portion of the battery so that as energy is generated during the day, a portion of their excess power is stored. During times of peak demand, this power can then be drawn on to power homes or otherwise support the grid.

Community batteries allow households and businesses that generate power to pool excess electricity in shared storage for later use. A community battery is connected to the wider grid, and while predominantly intended to store energy for local use, it is not restricted to just charging from energy

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[1] Based on approximately 3.8 million solar PV installations (see Clean Energy Council - Small Scale Installation Data) and 10.8 million households (Australian Bureau of Statistics, 2021 Census).

[2] Based on approximately 2.5 million solar PV installations (see Clean Energy Council Household Solar and Storage Report (2023)) and 10.8 million households (Australian Bureau of Statistics, 2021 Census).

[3] Clean Energy Council Household Solar and Storage Report (2023)

[4] https://bsgip.com/news-events/news/maximising-insights-from-neighbourhood-battery-projects/

generated locally. It can be charged with surplus solar energy from local households and businesses, or with electricity from a distant power plant. The battery is unlikely to meet all the electricity needs of the neighbourhood, so households will still need to get electricity from the grid.

Community-scale batteries have the potential to play an important role in the global transition to a decentralised grid and offer an alternative to individual households purchasing their own battery storage systems, making storage more accessible to the public.

1.2 Benefits of community batteries

Energy storage can contribute to solving some of the problems in our energy system.

1.2.1 Technical benefits

Having a flexible resource like a community battery embedded in the local distribution system brings several technical benefits.

Improved local network stability by responding to voltage and frequency fluctuations

As the grid changes, the demands on local networks will grow. Increasing penetration of distributed resources (particularly rooftop solar and electric vehicles) means distributors can expect increasingly peaky and volatile loads, more voltage issues, and, eventually, a need to curtail residential solar.

Lithium-ion batteries are currently one of the most cost-effective forms of flexible storage[5], and can act quickly in response to grid fluctuations.

Improved resilience

Community batteries can improve power system resilience by providing a local source of energy, reducing the impact that grid outages, weather events, and natural disasters have on local consumers.

Battery storage with duration ranging from one to four hours aligns well with New Zealand outage metrics[6]:

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[5] See CSIRO Solar and Battery Projections (2023). The capital cost of a small-scale battery storage system is estimated at just over AU$1,400 per kW (2021 dollars).

[6] Commerce Commission: Performance Summaries for Electricity Distributors.

- SAIDI[7]: Four hours and 46 minutes (unplanned: three hours and 11 minutes, planned: one hour and 35 minutes);
- CAIDI[8]: Five hours and 31 minutes (unplanned: one hour and 39 minutes, planned: Three hours and 52 minutes);
- SAIFI[9]: 2.35 outages per year (unplanned: 1.94, planned: 0.41).

That is, depending on the total storage, batteries can contribute meaningfully to reducing average outage durations for local customers. Particularly, batteries can be used to improve resilience in remote parts of the distribution network.

Reduced network losses

Australian National University (ANU) found that, depending on the ownership and operation model, neighbourhood batteries could reduce local network exports by 15-20%, further helping to stabilise the grid by keeping energy local, and reducing the use of network equipment[10].

Better efficiency of network assets at times of high demand

A large, shared battery is better able to mitigate network congestion at peak times by managing power flows into and out of the local network than residential behind-the-meter (BTM) batteries of equal total storage capacity. The superior performance arises because a single large battery can direct all its capacity to the worst peaks in aggregate net load/solar, whereas un-orchestrated BTM batteries operate independently of each other and are not generally configured to respond to overall network trends.

Optimising the use of rooftop solar generation

Solar energy is generated during the day when the sun is shining. During periods of high solar output, a household may generate more energy than it needs to meet its own demand. If this excess energy cannot be used, stored, or exported to the grid, it is wasted.

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[7] System Average Interruption Duration Index (SAIDI) is a measure of the average length of outage experienced by customers, including those who experience no outages.

[8] Customer Average Interruption Duration Index (CAIDI) is a measure of the average length of outage experienced by customers who experience an outage.

[9] System Average Interruption Frequency Index (SAIFI) is a measure of the average number of outages experienced by each customer each year, including those who experience no outages.

[10] https://arena.gov.au/assets/2020/08/community-batteries-cost-benefit-analysis.pdf

Increasing solar generation can also cause congestion in the electricity network, such that the solar spill from households can be too much voltage for those local networks to handle, and therefore cannot be exported into local networks without breaching network security and reliability standards. In South and Western Australia this issue has been addressed with an emergency solar curtailment scheme, whereby rooftop solar is curtailed if the Australian Energy Market Operator (AEMO) deems that high levels of solar generation pose a credible power system security risk. However, such schemes require regulated inverter standards and do not make good use of the renewable energy being spilled by residential installations.

Community batteries can help integrate more distributed energy resources into the network, allowing greater benefits from generation of residential solar energy.

1.2.2 Social benefits

While the cost of distributed solar PV has rapidly declined in the last 20 years[11], many households will not be in a financial position to fund the up-front capital costs of installation. Community-scale batteries may help resolve this inequality, allowing more people to access renewable, affordable, local energy generation being shared by their neighbours who are creating more electricity than they need.

Social benefits are dependent on the design of a community battery scheme. A scheme tailored only to solar PV owners would limit the benefits to those who can afford solar but not a battery.

Community batteries also provide opportunity to build engagement with end-users, increasing trust in the energy sector, along with consumer knowledge that can lead to greater support for new technology as it comes online. If a community is to have a connection to the battery, proponents need to be transparent about what services the battery is providing and where benefits accrue. Even without financial involvement, community members can develop a sense of ownership if they:

- Are informed about how a battery functions and what it means for the community;
- Have a say in design and operation.

A battery can be a symbol of the community's commitment to climate action and energy sharing, providing a focal point for energy efficiency and conservation efforts. The Yarra Energy Foundation (see section 2.4) made its battery installation a piece of community art[12].

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[11] IRENA analysis of Australian solar PV costs

[12] Fitzroy North Community Battery – Yarra Energy Foundation (yef.org.au)

1.2.3 Economic benefits

Many of the technical benefits identified above also bring economic benefits:

- Reduced network losses and congestion allow greater use of low-cost renewable energy;
- Reduced or delayed network investment means lower network costs;
- Reduced incidence of outages for local consumers mean the system avoids the high cost of "lost load";
- Energy shifting from off-peak to peak lowers consumer bills.

Community batteries also provide economies of scale compared to distributed residential batteries. A single large battery will cost less for each unit of storage, reduces the number of system communication and control components, and consolidates installation and maintenance burdens[13].

However, many of the trials reviewed found that net benefits were either negative or required subsidies and/or specialised network tariffs to yield a positive net benefit. Nevertheless, economic benefits are just one type of benefit that can arise from community batteries. Other benefits may include decarbonisation, providing consumers with a sense of autonomy regarding energy decisions, and community resilience.

1.3 Challenges for community batteries

The ANU Battery Storage and Grid Integration programme summarised common risks and challenges encountered by Australian community battery projects, as shown in Figure 1.

[13] The benefits of neighbourhood batteries - Battery Storage and Grid Integration Program (bsgip.com)

Figure 1: ANU BSGIP - Community battery risk matrix[14]

	Minor (minor delays, additional cost)	Moderate (significant delays, costs, or changes)	Major (risk to viability of project)
Likely	• Challenges finding sites • Concerns and questions from community members • Supply chain delays	• Conflicts within community group/project team • Difficulty demonstrating benefit to community, managing expectations • Difficulty finding sites • Lack of relevant expertise	• Network data unavailable • Project team burnout • Lack of appropriate tariffs
Moderately likely	• Insurance costs more than expected • Contract negotiations protracted • Delays with connection agreement • Difficulty finding installer • Funding agreement delays • Delays in reaching DNSP	• Difficulties accessing network data • Problems with partners (lack of alignment, contracts) • Unrealistic goals, difficulty finding working models (accessing revenue streams) • Project team turnover • Costs blow out (e.g., poor cost estimates, under-resourcing) • Energy market changes affect revenues • Delays in battery procurement (e.g., tenders) and delivery • Difficulties with certification and compliance • Finding a suitable retailer • Problems integrating software and hardware (e.g., Software API communication)	• Budget shortfall • Problems negotiating connection agreement (including network changes affecting support of DNSP) • Major supply chain delays • Land availability • Regulatory change

[14] https://bsgip.com/knowledge-hub/risks/

	Minor (minor delays, additional cost)	Moderate (significant delays, costs, or changes)	Major (risk to viability of project)
Unlikely	• Extreme weather disrupts installation • Battery malfunction • Local election delays launch	• Project team major illness • Lack of support from community • Battery lifetime shorter than expected • Global pandemic	• Opposition from community • No response from DNSP • Difficulty partnering with retailer • Failure to provide proposed services, generate expected revenue

Negative impacts of community battery projects are largely restricted to financial losses if a project is not designed and implemented carefully. For example:

- Consumers paying for use of a shared battery could be worse off financially if they do not have sufficient solar to store, or peak usage to offset. This can be mostly addressed by a careful onboarding process.
- Network savings could be less than expected, leading to increased capital expenditure. The likelihood of this will diminish over time as technology costs reduce, and more experience is gained with battery deployment.

Finally, as evidenced by each rollout of a new generation of telecommunications technology, some community members have general concerns about noise and radiation from Electromagnetic Fields (EMF) from electronic equipment. Community battery projects need to be ready to demonstrate the testing and mitigation measures in place to assuage those fears.

2 AUSTRALIAN TRIALS

2.1 MAIN FINDINGS

In Australian community battery trials, the main measurement of success is the quantifiable reduction in electricity bills of trial participants. The main finding from the trials was that community-scale batteries can be installed and used in Australia without major changes to current regulations, but the financial viability of almost all community-scale storage projects will be best supported by special local network battery tariffs. For example, ANU modelling found that community battery trials would only be financially feasible if network tariffs were discounted; under existing tariffs batteries incur cost for charging and discharging resulting in the system being "double-charged"**15**. This issue could be addressed by introducing Local Use of System (LUOS) charges that discounts energy flows within a neighbourhood or through PEER-TO-PEER trading.

2.2 ALKIMOS BEACH TRIAL (2016-2021)

The Alkimos Beach Energy Storage trial (2016-2021) in Western Australia, was one of the first trials of community batteries in Australia[16], where Synergy represented the electricity retailer and LendLease the property developer. Alkimos beach was chosen as all homes have solar panels, as part of an Energy Smart Home package.

- The trial commenced in April 2016 with the installation of a 1.1 MWh Lithium-Ion battery. The Australian Renewable Energy Agency (ARENA) provided $3.3 million in funding through its Emerging Renewables Program.
- Trial participants were charged for their electricity based on the time of day it was consumed (known as a time-of-use tariff)[17].

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[15] Neighbourhood Batteries in Australia

[16] alkimos-beach-energy-storage-trial-report.pdf (arena.gov.au)

[17] The 'time of use' tariff was divided into three time bands with the same rate for electricity use during the Off-peak Day (midnight - 4pm) and the Off-peak Evening (8pm – midnight) bands, while electricity use during the Peak Daily period (4pm - 8pm) was charged at a substantially higher rate. Therefore, if participants use more energy during the Peak Daily period than they have stored as credits from the solar they generated that day, they pay for the extra electricity consumption at a higher rate.

- Participants were able to make the most of their solar PV system by virtually storing the excess energy generated. Participants were charged a $11 per month battery storage fee.

The 119 households which participated saved a total of $81,376 over five years, with an average of $683.83 per participant for the duration of the trial. There was also an 85 percent reduction in local energy consumption during peak periods. However, the $11 a month battery storage fee was highly subsidised and would not be otherwise commercially viable. The trial report indicated that the trial delivered both economic and non-economic benefits: *"the utilisation of the community battery storage during these peak periods reduced demand on the network,* ***which proved to provide benefits to system security and Synergy as an electricity retailer****.....to test the feasibility of a new servicing model; delivered economic and non-economic benefits to participants, Synergy as the electricity retailer and LendLease as the property developer; and* ***provided learnings to shape the future of land developments with large-scale community energy storage****."* The trial further concluded that virtual battery products are best for customers who export in the middle of the day and consume in peak times.

2.3 WESTERN POWER POWERBANK TRIALS (2018-2021)[18]

Western Power (Western Australian network utility) and Synergy (generator-retailer) partnered to install three community-scale batteries utilising Tesla technology:

- Meadow Springs, Mandurah: first trial launched in October 2018 with a 105kW (420kWh) battery
- Falcon, Mandurah: an extension of the Meadow Springs trial with a 116kW (464kWh) battery
- Ellenbrook: a PowerBank trial launched in February 2020 with a 116kW (464kWh) battery

Western Power owns and maintains the batteries. Customers are allocated 6kWh or 8kWh of virtual storage and pay $1.60 or $1.90 a day for access to the battery.

Households store excess solar energy during the day and draw energy back from the battery to power their homes during the afternoon peak from 3pm to midnight. At midnight, any excess power still in the battery is returned to the grid, with the householder paid the standard feed-in tariff.

The first trial in Meadows Springs involved 44 residents. In the first year of the trial:

- Participants stored an average of 7.38kWh of solar energy per day;

[18] Western Power and Synergy Powerbank trials

- Participants consumed an average of 5.23kWh from the battery per day;
- 95 per cent of customers saved money on their power bills;
- Participants saved a total of AUD$11,000, an average of AUD$228 per household over the duration of the trial.

2.4 Fitzroy North trial (2022-present)

In June 2022, the Yarra Energy Foundation (YEF) launched Victoria's first inner-urban community battery in Melbourne's Fitzroy North. The project installed a 110kW / 284kWh battery, funded by the Victorian Government's Neighbourhood Battery Initiative (NBI)[19].

The total cost of the project (including in-kind work) was nearly $1.5m, for a cost of around $1,100/kWh. Of this, about half was provided by the NBI grant. This cost was higher than expected due to the connection and artwork costs. Software development was more than half of the total funded work.

The battery has helped to stabilise the grid and time-shift excess local solar energy from daytime to the evening peak. It has helped to remove solar waste, reduce energy prices, enable more solar installs, and increase community-wide access to locally produced renewable energy.

The project identified some financial issues that are important for a project to provide a return:

- Under standard network tariffs, the battery would pay a demand charge and a per-kWh charge. The distributor agreed a special Local Use of System tariff which recognised the contribution of the battery to the local network. The tariff included a fixed daily charge, and then a two-sided (import/export) time of use variable tariff, where the distributor paid the battery owner for consumption in the middle of the day and injection at peak, but the battery operator would pay a very high charge for consuming during the peak period – an unlikely scenario. The specialised tariff incentivised consumer behaviour that supports the power system and contributed greatly to the financial viability of the project.

[19] See Yarra-Energy-Foundation-NBI1-Final-Report.pdf (yef.org.au). Note, this was a non-commercial project.

- There were significant operational expenses involved in running the battery – estimated at around $17,000 per year[20]. Without a subsidy, this level of operating expenditure would render a commercial project non-viable. Note, much of this cost is fixed, so a larger battery programme would allow spreading these costs over a larger revenue base.

2.5 OTHER TRIALS

Three other trials have not published final reports.

Yackandandah microgrid development trial

Retailer Indigo Power partnered with community group Totally Renewable Yackandandah (TRY) to install a 65 kW solar array coupled with a 274 kWh battery in Yackandandah, Victoria in 2021. This installation was part of local microgrid trials[21], where local households had solar installed, and some had smaller, behind the meter batteries. The battery site and each household is managed by a smart energy controller (Mondo Ubi), which in turn communicate with a central microgrid platform[22]. The local and central systems manage the cycle of charging and discharging of the batteries, optimizing energy utilization by charging during the day and discharging in the evening.

A distinguishing feature of the Yackandandah trial is that the battery is installed behind-the-meter. The ability to install the system at a local sawmill with a large existing network connection avoided the need for additional network connection expenditure.

Stored energy is not directly linked with local solar injection. Indigo operates as a social enterprise, sells energy exported by the microgrid sites to others in the community at discounted rates, and returns 50% of profits to the community.

The group is now preparing for a second community installation – a 200 kWh RedFlow bromine flow battery at the local sports park[23].

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[20] The $17,000 cost is OPEX for a low-voltage single system and includes costs for administration, IT operations (hosting, management and maintenance), metering, system maintenance, site maintenance, and insurance. The figure excludes software license fees, offline research and analysis, retailer/aggregator costs (netted out of market revenues), and land-lease fees. The report noted that OPEX for a single system can vary depending on commercial and technology arrangements.

[21] Project: Yack01 Community Battery – Totally Renewable Yackandandah

[22] Totally-Renewable-Yackandandah-microgrid-public-report.pdf (energy.vic.gov.au)

[23] https://totallyrenewableyack.org.au/kookaburra/wp-content/uploads/2023/11/2023-10-25-AGM-Presidents-Report.pdf

Ausgrid community battery trial

Australian East Coast electricity distributor Ausgrid ran a community battery trial from 2021 to 2023, with batteries in three New South Wales locations: Cameron Park, Beacon Hill and Bankstown. Local customers were offered 10kWh per day of storage at no charge, allowing them to store excess solar energy, which was then credited against the participant's daily electricity consumption. The credit was tallied daily and paid to the participant quarterly via bank transfer. Participants did not have to change their electricity retailer to participate.[24]

Ausgrid is currently carrying on another trial in six other locations.

United Energy pole-top battery trial

Australian network provider United Energy is currently engaged in the deployment of 40 30 kW 66 kWh batteries on power poles around Melbourne[25], sufficient to power up to 75 households.

The main benefit for United Energy is peak reduction. Two example installations in Melbourne's neighbourhoods of Highett and Black Rock delivered a reduction in local peak demand ranging between 10% and 20%. When not being used for this service, batteries are managed by Simply Energy (retailer).

[24] Community battery trial - Ausgrid

[25] Electric Avenue pole-top battery program - United Energy

3 BUSINESS MODELS

Community battery projects can operate in a variety of ways, depending on their goals. Three key elements of a project are who owns it, who operates it, and how it makes money. Trials to date have explored the three possible owners:

- A retailer
- A distributor
- A third party (which could include local government).

The ideal ownership model depends on the location, neighbourhood characteristics, and project goals. In addition, the ability to value-stack greatly impacts the commercial attractiveness of a project. For example, a retailer could invest in community batteries for multiple use cases. It could:

- Use the batteries for arbitrage and manage its exposure to wholesale electricity spot prices.
- Offer services to local distribution companies to provide network flexibility services such as constraint management (peak reduction), voltage support and network restoration services.
- Offer balancing and ancillary services to the power system operator.

Accessing multiple revenue streams would make the investment more attractive, but the ability to value stack depends on whether:

- The regulatory framework enables the retailer to provide these services (e.g. through defined services or a contractual mechanism). The New Zealand regulatory framework largely enables the retailer to provide such services, although doing so relies on electricity network businesses being prepared to purchase the services.
- There is business-to-business and coordination infrastructure that enable these services to be delivered without adverse impact on power system and network security and reliability.

3.1 EDB OWNERSHIP

Electricity Distribution Business (EDB) ownership is the most prevalent model in trials to date. EDBs know the limitations of the local network, have the best understanding of where a community battery could be located to mitigate congestion or delay network expenditure, and have incentive to adjust network tariffs to reflect the benefits provided[26].

While these benefits can be significant, in Australia, EDB ownership restricts access to other revenue streams, because they are not allowed to participate in wholesale energy and ancillary service markets. EDB operation is restricted to use for regulated network support services, reducing the potential for regular charging and discharging to shift energy from the middle of the day to the peak. This is similar to New Zealand, where there are generation ownership restrictions on EDBs which prevents them from participating in the wholesale energy and ancillary services market.

Energy sharing and gifting can potentially be supported by network owned batteries, but to make full use of the potential flexibility, some or all of the capacity can be leased out to an operator who is allowed to participate in those markets. This model has been used at transmission level – for example the 30 MW 8 MWh Dalrymple ESCRI-SA battery in South Australia[27] – but doing so at distribution level is more difficult due to the smaller sizes involved.

3.2 Retailer ownership

In this model, the community battery is owned by a retailer. Retailer ownership offers the smoothest connection with consumers, as the retailer already participates in electricity market processes, and has billing and metering relationships with consumers.

The retailer could sell access to storage to individual consumers (such as in the Western Power Powerbank trials), charging a fixed fee (daily, annual, or up-front). It could facilitate neighbourhood energy sharing without charging a fee.

A retailer could build distribution embedded storage without engaging the community and operate it purely to manage its own exposure as part of its overall generation portfolio. Such a use case might make sense in a neighbourhood where the retailer has a significant number of customers with distributed generation. It would still be a community battery but would not necessarily be for the benefit of the community.

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[26] The extent to which an EDB can accurately identify the location and magnitude of network constraints will depend on the extent of network digitalisation. Incentives to digitalise the network will depend heavily on whether the regulatory framework governing EDBs provides the requisite incentives for EDBs to make investments whose benefits are realised outside the regulatory reset period and for EDBs to spend OPEX over CAPEX.

[27] Dalrymple ESCRI-SA Battery Project – ElectraNet

Retailer ownership could make it more difficult for participants to see a battery as a community resource, particularly where the retailer is free to operate the battery to maximise its own profit, without passing benefits to community members. This can be mitigated through contractual provisions between the retail and the consumer to ensure savings are passed onto the community.

The retailer would still need to engage with the local distributor to discuss appropriate network tariffs, and potential payments for network support services.

3.3 THIRD PARTY OWNERSHIP

While EDB and retailer ownership have been the norm, it is also possible for third parties to own and operate a community battery. Examples are community trusts, local governments, or private companies.

An independent owner could prioritise profit but can also choose to prioritise equity and decarbonisation. Such an owner has access to the same revenue streams as a retailer owner.

The challenge for an independent owner is that they do not have the pre-existing knowledge and relationships of an EDB or a retailer and may need to put in significant time and effort to build them. Organisations with good community connections often have financial constraints that make it difficult to fund the initial capital expenditure required in the absence of grants, low-interest finance, or direct capital contribution by prospective users.

The Fitzroy North trial (section 2.4) involved a community group owning and operating the battery.

3.4 OWNERSHIP AND FUNDING FOR PAST TRIALS

Table 1 summarises ownership and funding models for some of the Australian trials discussed in chapter 2.

Table 1: Ownership models for Australian battery trials

Community battery trial	Funding	Ownership	Operation	Comments
Alkimos Beach, WA	ARENA grant	Property developer (LendLease)	Retailer (Synergy)	Highly subsidised rate of $11 per month charged to participating consumers. Likely to be commercially non-viable without the subsidy.
Western Power Powerbank Meadows Springs, WA	State-owned network operator Western Power partnered with generator and retailer Synergy	Distributor (Western Power) Retailer (Synergy)	Distributor (Western Power)	Unlikely to be commercially viable without cost-reflective tariffs. A TOU tariff was used for this trial. However, almost all non-contestable customers in WA are on a subsidised retail tariff that means consumers have limited incentive to reduce peak consumption.
Fitzroy North, VIC	50% Victorian Government's *Neighbourhood Battery Initiative* NBI grant, contributions from YEF and CitiPower	Not for profit community group (Yarra Energy Foundation (YEF))	Not for profit community group (YEF)	The trial concluded that • batteries are currently too expensive (relative to revenues) for the project to be commercially viable. • Batteries would need to at least halve in the price and additional revenue streams would be needed for commercial viability. • Using standard network tariffs would have made the project commercially unviable. A special TOU tariff was used for this trial.

Community battery trial	Funding	Ownership	Operation	Comments
Ausgrid, NSW	East Coast electricity distributor Ausgrid	Distributor (Ausgrid)	Distributor (Ausgrid)	
Yackandandah, VIC	AUD$104k, Indigo Power AUD$100K and Victorian Government's *Neighbourhood Battery Initiative* NBI grant AUD$171k	Retailer (Indigo Power)	Retailer (Indigo Power)	Consumers with solar panels benefited the most from the battery. Additionally, consumers with solar panels, hot water heat pumps and a battery had the greatest savings.
United Energy pole top batteries, Melbourne	United Energy AUD$7 million and ARENA grant AUD$4 million	Distributor (United Energy)	Distributor (United Energy) Retailer (Simply Energy)	

4 System sizing analysis

4.1 Background

How big a battery does a community need? To provide some high-level insights on potential battery and solar installation sizing, we have a developed a model that simulates solar generation, quantity of energy stored and potential sharing options for different sizes of solar PV systems and batteries.

4.2 Assumptions

4.2.1 Overview

Our model assumes the following:

- 15 households with solar panels that are 4kW in capacity with a capacity factor of 14%[28] (referred to as the solar households).
- Households are in Pukekohe, south of Auckland city.
- A 35 kW 120 kWh battery storage system to store excess solar during the middle of the day, for use by participating households. For this analysis, we have assumed:
  - Solar households will use the maximum quantity of generation to offset their own use. That is, excess solar only occurs when the quantity of generation exceeds the hourly consumption of a solar household.
  - The maximum quantity of solar excess is stored in the battery. For example, for a 120 kWh battery, up to 120 kWh of solar can be stored; anything above 120kWh would be exported (spilled) into the local network.
  - The energy stored in the battery will first be used to offset energy consumption of solar households.
  - Any leftover energy stored in the battery (after offsetting energy consumption of solar households) will be shared with other non-solar households.

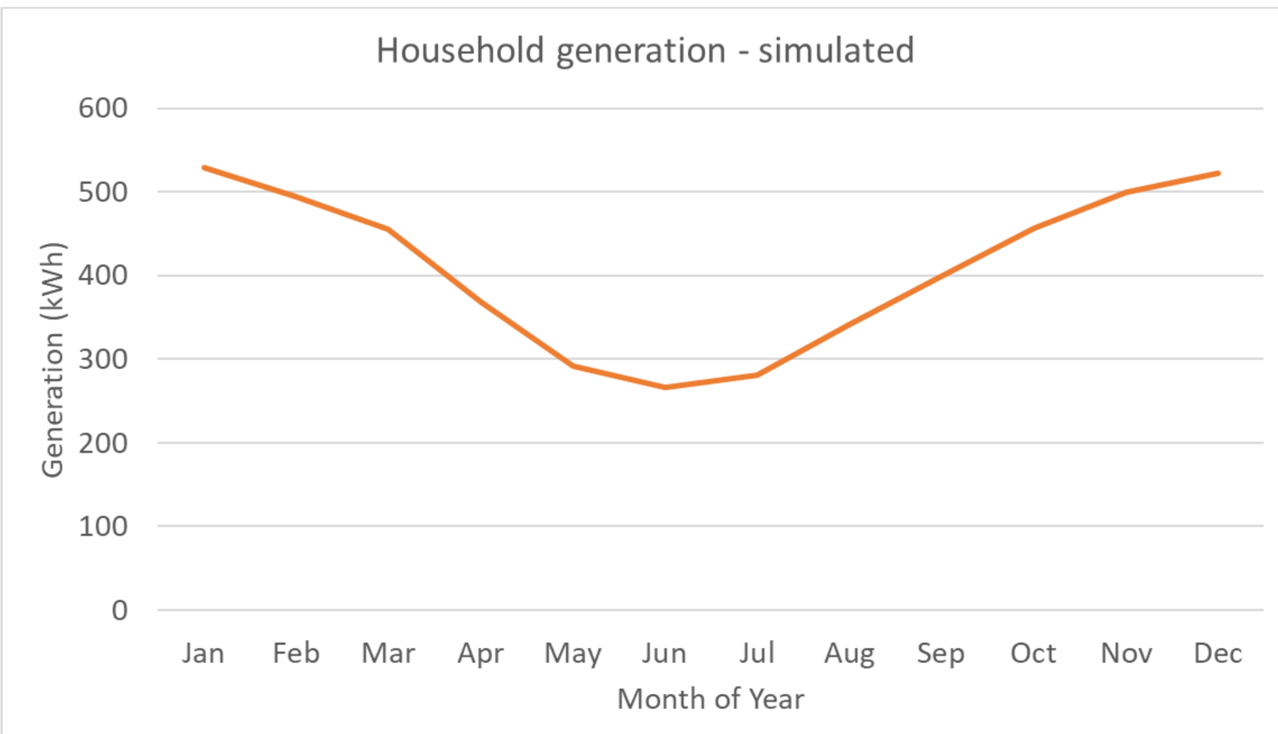
[28] The 14% capacity factor comes from in the Ministry of Business, Innovation and Employment's Energy In New Zealand 2023.

4.2.2 Generation data

To simulate hourly roof-top solar generation for a single household in Pukekohe we adopted the following approach:

- A 4kW system with a 14% capacity factor would produce 4,905.6kWh per year.
- Using hourly solar irradiance data for Pukekohe[29], we converted the annual production to an hourly output. Figure 2 summarises the profiled monthly generation (derived by summing the profiled hourly values for a given month).
- Generation estimates do not account for variations in weather within a month – i.e. all days in a month are assumed to have the same output, when in practice some days will be high and others low.

Figure 2: Profiled monthly generation for household solar system (aggregated using profiled hourly values).



[29] Solarview (niwa.co.nz)

4.2.3 Consumption data

Residential electricity consumption data was not available at hourly granularity. Consequently, we adopted the following approach:

1. We obtained average monthly residential consumption data (for the year 2023) from the Electricity Authority's Electricity Market Information (EMI) dataset, and converted this to daily averages (by dividing the monthly average by the number of days in a month).
2. We used Transpower's hourly national load dataset for the year 2024 to convert the daily average residential consumption to an hourly value. Transpower's dataset only allows users to download demand data for the most recent month. Consequently, we were only able to obtain hourly national demand data for May 2024. We used the May 2024 national hourly demand data to estimate residential hourly demand as follows:
   a. We first calculated the average hourly demand for May 2024 (from the Transpower dataset) ($\overline{National\ Demand_{h(May)}}$).
   b. We then applied the hourly profile from step 2a to the residential daily averages in Step 1 to obtain a residential hourly profile for the month of May:

$$Residential\ Demand_{h(May)} = \overline{National\ Demand_{h(May)}} \times \frac{\overline{Residential\ Demand_{d(May)}}}{\overline{National\ Demand_{d(May)}}}$$

   Where:
   - $Residential\ Demand_{h(May)}$ is the simulated hourly residential demand for the month of May ($h \in \{1,2,..,24\}$).
   - $\overline{National\ Demand_{h(May)}}$ is the average hourly national demand for the month of May 2024 calculated from Transpower's dataset in Step 2a above ($h \in \{1,2,..,24\}$).
   - $\overline{Residential\ Demand_{d(May)}}$ is the average daily residential demand for May 2023 calculated in Step 1 from the EMI dataset. ($d \in \{1,2,..,31\}$)
   - $\overline{National\ Demand_{d(May)}}$ is the average daily national demand for the month of May 2024 calculated from Transpower's dataset ($d \in \{1,2,..,31\}$).

   c. We then estimated hourly demand for residential households for other months by scaling the hourly residential estimates for May (calculated in Step 2b) by the ratio of the residential daily demand in May to the residential daily demand of month m (calculated in Step 1). That is:

$$Residential\ demand_{h,m} = Residential\ Demand_{h(May)} \times \frac{\overline{Residential\ Demand_{d(m)}}}{\overline{Residential\ Demand_{d(May)}}}$$

Where:

- $Residential\ demand_{h,m}$ is the simulated hourly residential demand for the month m.
- $Residential\ Demand_{h(May)}$ is the simulated hourly residential demand for the month of May calculated in Step 2b above.
- $\overline{Residential\ Demand_{d(m)}}$ is the average daily residential demand for a given day in month m calculated from the EMI dataset in Step 1.

4.3 RESULTS

4.3.1 Base case

(15 households with 4kW solar systems and a 120kWh community battery)

One of the benefits of community batteries is that households with solar can store excess exported energy which would otherwise be sold into the spot market.

Figure 3 illustrates the quantity of solar spill with and without a 120kWh battery. Without a battery, almost half the solar generation is spilled during peak solar months. On average, 36.4% of daily solar generation is spilled each year.

Introducing a battery drastically reduces this quantity to 2.1%. Solar spill only occurs in November and December when solar generation is the highest and there is insufficient storage capacity to store all the solar generation.

Figure 3: Average daily solar spill with and without batteries

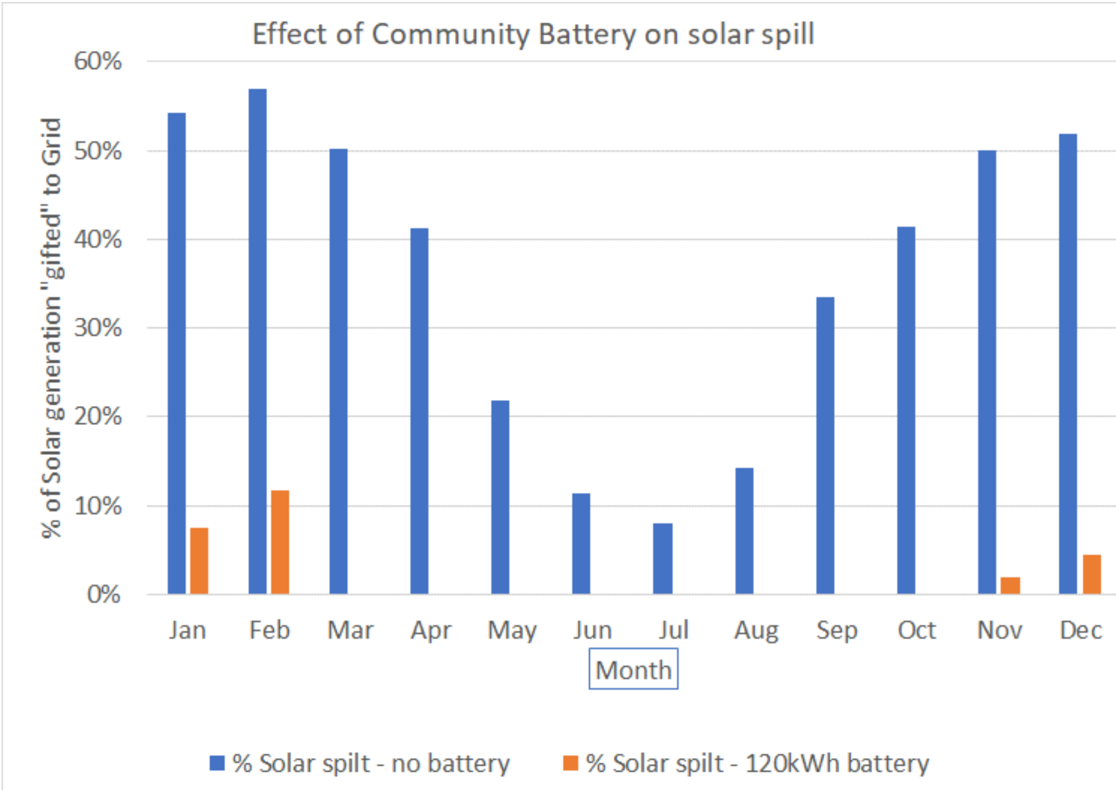
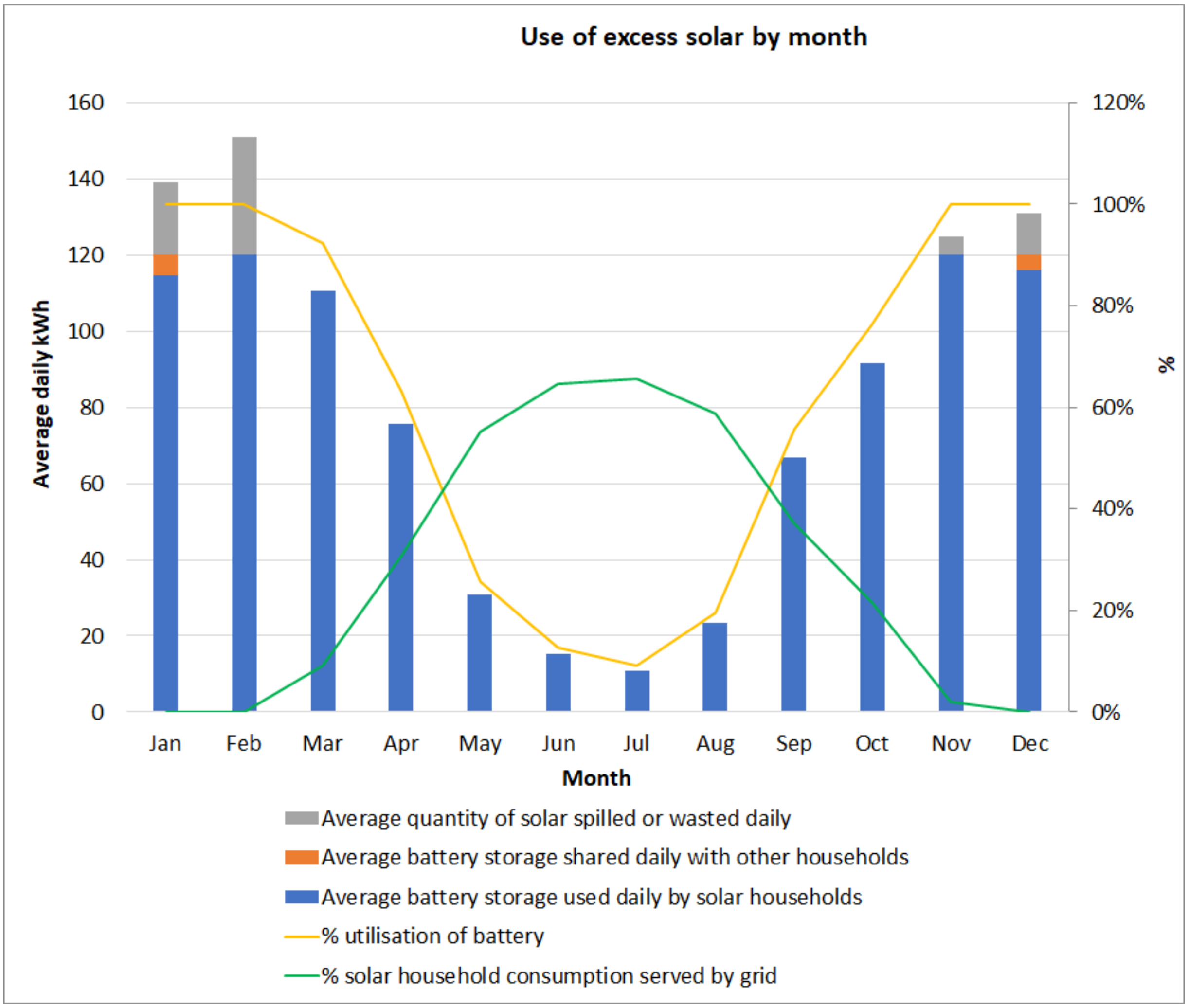


Figure 4 illustrates how the excess solar generated by solar households is distributed.

Figure 4: Average daily "use" of excess solar by month



- The blue portion of each bar represents excess solar stored and used later by households. As expected, in most months almost all the excess solar is stored in the battery and used only by the solar households.
- The orange portion of each bar represents excess solar stored which could be shared with non-solar households. With this size of battery, sharing with non-solar households is only possible in January and December, when solar generation is at its highest and consumption is lower (due to lower heating needs in these months). During these months:
  - Solar households generate more than enough to offset their entire daily demand and still have excess generation stored to share with other households.

- The quantity of excess storage available could be used to offset the demand of approximately 25% - 34% of the daily use of a single non-solar household (assuming each non-solar house has demand equal to the average daily demand for the given month).

- The grey portion of each bar shows excess solar which cannot be stored in the battery and is spilled[30]. As indicated in Figure 3, solar spill only occurs from November to February. This could potentially be shared with non-solar households at the time of production.
- The green line (measured on the secondary axis) shows the average proportion of a solar household's demand that is served by the grid. As expected, in summer months (December to February), solar households do not import from the grid as they can utilise their solar generation and the stored excess to offset all their use.
- The yellow line (measured on the secondary axis) denotes the percentage of the battery's storage capacity that is used on average on a given day in a month. As expected, all of the storage capacity is utilised in the summer months when solar generation is higher, and utilisation drops below 10% in the darkest months of the year (June, July) when solar generation is at its lowest.

4.3.2 Sensitivity analysis

The above analysis indicates that increasing the size of the solar panels and/or the size of the battery will increase the quantity of household energy use that can be offset by both solar and non-solar households. However:

- Increasing the size of the solar panel system without increasing the size of the Community Battery may result in much of the extra generation being spilled to the grid, while,
- Increasing the size of the Community Battery without increasing the size of the solar PV systems may result in the battery being under-utilised. As seen in Figure 4, the utilisation of the 120kWh battery decreases substantially in winter months when there is less solar generation.

[30] Theoretically, solar spill could be reduced by increasing consumption during high solar output periods to bring net consumption as close to zero as possible. However, this would require smart devices to be widely available. Furthermore, increasing consumption may not be in the consumer's best interests. For example, if the consumer is not home during the day, there is limited benefit to the consumer increasing the temperature on a smart heat pump (unless they are being compensated to do so, e.g., for a service to provide grid security services to address low operational demand).

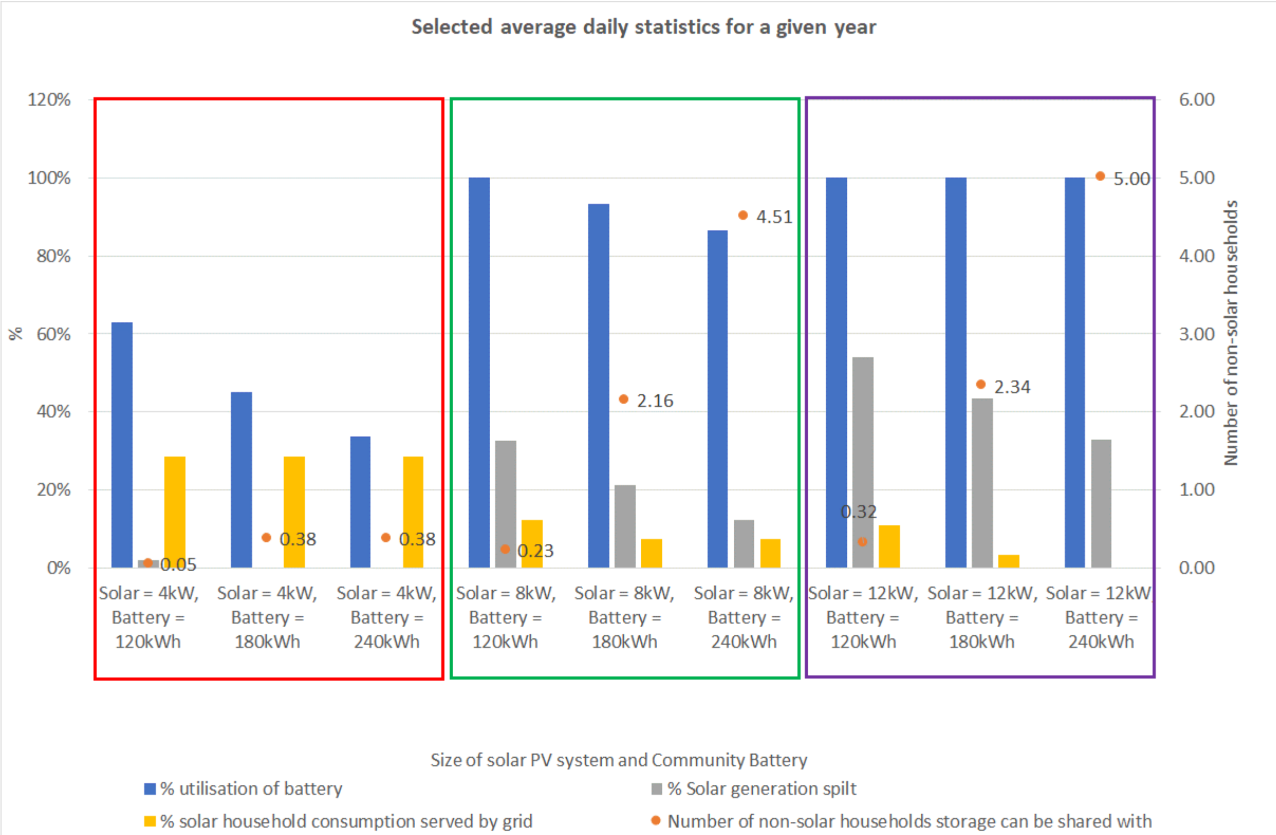
For this reason, the size of the solar PV systems and the Community Battery must be selected carefully to maximise the benefits to the community (via offsetting grid-served demand with rooftop solar PV production and battery discharge) while ensuring the Community Battery is not under-utilised.

Figure 5 summarises selected average daily statistics for nine different scenarios with varying combinations of solar PV system size (4kW, 8kW and 12kW) and Community Battery size (120kWh, 180kWh and 240kWh).

We summarise the following average daily statistics (with all statistics averaged across the entire year to simplify presentation):

- % utilisation of battery: this denotes the average proportion of the battery's full capacity that was utilised daily throughout the year.
- % solar generation spilled: this denotes the average proportion of daily solar generation sold to the grid (as the battery did not have sufficient capacity to store all the excess solar generation)
- % solar household consumption served by grid: this denotes the proportion of a solar household's daily consumption that was provided by the grid (as opposed to offset using solar generation and battery discharge).
- Average number of non-solar households whose daily use could also be covered using the charge held in the Community Battery (after offsetting the use of the solar households). This is measured on the secondary axis.

Figure 5: Average daily statistics by system characteristics



Solar installation size, 4kW

The highest battery utilisation for a 4kW solar installation is observed for the 120kWh (63%) with only minimal daily spilling (0.05kWh on average, with the highest spills occurring in the summer months as shown in Figure 3). While there is no spill with the larger sized batteries, the utilisation of the battery drops significantly to 45% for a 180kWh battery and 34% for a 240kWh battery.

Given 15 solar households, the quantity of excess solar that can be shared with non-solar households is minimal irrespective of the size of the battery – this is because the generation from a 4kW solar installation is insufficient for sharing energy with non-solar households.

Solar installation size, 8kW

Increasing the solar installation size to 8kW results in the following:

- Higher utilisation of the Community Battery for all three sizes (120kWh, 180kWh and 240kWh). This is expected as there is more energy to store with an 8kW system.

  - Battery utilisation ranges from 87% (for a 240kWh battery) to 100% (for a 120kWh battery). As noted below, there is some solar spill even with the largest battery size.
- The quantity of solar spilled ranges from 12% (for a 240kWh battery) to 33% (for a 120kWh battery).
- Energy sharing with non-solar households is possible with the larger battery sizes:
  - On average, the daily demand of 2.16 households can be met with a 180kWh battery.
  - With a 240kWh battery, this increases to 4.51 households.

Prima facie (noting that this analysis does not consider financial net benefits), an 8kW solar installation paired with a large battery (180kWh – 240kWh) enables meaningful sharing with non-solar households while ensuring high battery utilisation and keeping solar spill to a minimum.

Solar installation size, 12kW

Increasing the solar installation size to 12kW results in the following:

- The Community Battery is 100% utilised for all battery sizes. This is because of the higher production of the 12kW installation.
- At the same time, however, the quantity of solar spilled increases significantly for all battery sizes, ranging from 33% spilled for a 240kWh battery to 54% spilled for a 120kWh battery. The higher spill rates occur because even with a 240kWh battery, a 12kW solar installation will produce too much energy to store.
- As with the 8kW system, energy sharing with non-solar households is possible with the larger battery sizes. However, the additional number of households served with a 12kW system (compared to the 8kW system is minimal).
  - On average, the daily demand of 2.34 households can be met with a 180kWh battery (compared to 2.16 households with an 8kW system)
  - With a 240kWh battery, this increases to 5 households (compared to 4.51 households with an 8kW system).

The minimal increase in sharing occurs because any additional energy produced by the large solar installation is likely to be spilled (i.e., an 8kW system would require a larger battery to reduce spill and enable greater sharing with non-solar households)

The above indicates that a 12kW solar installation would result in larger quantities of solar being spilled while not enabling much additional sharing (when compared to the 8kW system).

5 KEY INSIGHTS

Use cases vary and can impact on net benefits and the parties to which these benefits accrue

There are two broad categories of use cases that Community Battery trials can test:

- Electricity cost management via utilising stored excess solar to offset energy use later in the day and/or to share energy with others.

  Here, the consumer benefits through lower energy bills which occur because of the consumers reducing the quantity of energy that is served by the grid. That is, the consumers are using solar generation and stored solar (used to offset their own generation or gifted to others) to reduce the level of consumption that is billed at their standard retail tariff rate.

  Depending on the role of the retailer in the trial, the retailer can also benefit from reduced exposure to high spot prices (due to the peaks being smoothed).

- Flexibility services provided to network operators or power system operators including:
  - Network support services such as capacity management or network balancing. Network capacity management services use the stored energy in the battery to shift and reduce demand in peak periods, thereby enabling the network owner to defer or avoid network augmentation. Network balancing services can include reactive power (or voltage management) or system restoration services.
    Here, the consumer benefits through:
    - A financial payment for their solar excess or through special tariffs that reflect the cost of using the network during different time periods (so that using the stored solar during peak periods results in lower network charges).
    - Longer term reductions in network charges
    - Reductions in energy charges, with the size of the reduction depending on how cost-reflective their retail tariffs are. For example, a customer on a spot exposed tariff would enjoy lower energy charges, as discharging the battery during peak periods may reduce their exposure to high spot prices.

    At scale, all consumers benefit, by reducing peak spot prices.
    Network flexibility services are highly locational in nature, so the location of the Community Battery will be critical with respect to maximising benefits.

– Power system balancing where the stored energy in the battery is used to provide ancillary services to the power system operator. As above, the customer would benefit from:
    - A financial payment for their solar excess.
    - Reductions in energy charges.

  At scale, all consumers benefit, as batteries are used to enable greater penetration of low short-run marginal cost intermittent renewable generation.

Trials seldom deliver positive net-benefits and may require specialised tariffs

Almost all the trials we reviewed received government funding and would not have been viable without the funding. This is, at least in part, related to the high capital costs of batteries which should decline over time. Another insight from the Australian trials is that where the operating expenditure has a large fixed-cost component, using a larger battery to spread the costs over a larger revenue base will make the net benefits more attractive.

Additionally, many of the trials required specialised network tariffs to make the trial financially viable. Deploying network capacity management or network/system balancing use cases requires the consumer's financial incentives to be aligned with the incentives of the party that is using the stored solar (flexibility user)[31]. For this to occur, retail and network tariffs must be cost-reflective and provide a clear signal to the consumer. New Zealand has full retail competition which means retailers can offer time-of-use tariffs that better reflect the impact of consumption on the power system. However, general network tariffs are not necessarily cost reflective[32] (particularly tariffs with a per kWh network charge that is the same at all hours of the day). This means that the trial may need special tariffs for the consumer to be incentivised to participate[33].

Value stacking can make benefits more attractive but adds complexity to the trial

Another way to make a trial more attractive is to use the battery to serve multiple use cases (value-stacking). This increases the revenue stream from the battery.

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[31] For example, flat network tariffs that do not vary by time do not incentivise a consumer to reduce their consumption during peak periods (even though doing so would benefit the network operator and all consumers in the longer-term by deferring network augmentation). By contrast, a time-of-use tariff that is more expensive during peak periods would better align the consumer's incentives with the incentives of the network operator.

[32] The Electricity Authority has a work programme focussing on distribution pricing reforms.

[33] In New Zealand, EDBs set network tariffs based on their regulated price paths that are set by the Commerce Commission. These charges flow to consumers through retail bills with retailers passing on the network charges from their consumers to EDBs. The Electricity Authority is currently investigating distribution pricing reform as one of its projects.

However, value stacking does add complexity and therefore cost to the trial:

- Service definitions need to be developed that will govern the use cases provided by the battery. There are currently no developed markets for network flexibility services in New Zealand, meaning ad-hoc services would need to be developed.
  - For example, energy and Instantaneous Reserves are defined services in the Code; a provider wanting to provide such a service can register in the wholesale market and provide these services (subject to meeting technical requirements). By contrast, there are no defined services or markets for network support services such as peak shifting/reduction, voltage regulation, etc. This means that the procurer of a network support service must develop ad-hoc service specifications for their needs and bilaterally contract with potential providers.
  - While ancillary services (such as Instantaneous Reserves and Frequency Keeping) are defined in the Electricity Industry Participation Code, Community Batteries may not be set up with the measurement and monitoring infrastructure to participate in those markets under existing regulatory conditions. As such, exemptions may need to be sought to tailor the service definitions for the purposes of the project.
- Where there are multiple purchasers or users of flexibility services[34], the appropriate business-to-business and business-to-market infrastructure must be set up to ensure different parties can receive the information[35] they need. The more parties involved, the more complex this set-up.
- As highlighted above, the provision of energy, network and ancillary services will likely require specialised tariffs to be developed for participating consumers.

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[34] Users of flexibility services include:

- The power system operator who may procure flexibility from a community battery for grid balancing services (energy, ancillary services)
- The network operator who may procure flexibility for network supports services such as peak shifting, voltage regulation and outage management.
- An energy retailer who procures flexibility to manage the energy costs it faces (i.e., contracting consumers to discharge their batteries during peak intervals can reduce demand and therefore the spot price which results in lower costs for the retailer).
- The consumer who uses the stored energy in the community battery to reduce household energy costs.

[35] For example, metering information, bids and offers for various services, dispatch instructions or dispatch constraints (that the power system operator or network operator must be aware of), dynamic operating envelopes (that restrict the export of the community battery), device/inverter level information (e.g., for assessing compliance with technical standards), etc.

Additionally, EDB ownership of the battery can make value stacking more difficult. In both Australia and New Zealand, network owners can invest in batteries for network capacity management and other network use cases. The battery asset becomes part of their regulatory asset base so that the network owner can earn a return on the battery. As the battery is a regulated asset, the network owner may not be allowed to use it for other purposes to earn additional revenues on that asset. Moreover, network owners are prohibited in providing non-network services in both Australia and New Zealand. As such, the network owner may need to lease part of the capacity to a retailer (which would have to be excluded from the network owner's regulatory asset base). This was the approach used in the Western Australian PowerBank trials.

Retailer ownership of the Community Battery is the simplest option, but there are challenges in ensuring benefits flow to participating consumers

As previously discussed, retailer ownership offers the smoothest connection with consumers, as the retailer already participates in electricity market processes, and has billing and metering relationships with consumers. Some New Zealand retailers offer solar sharing programmes which could accommodate community battery additions with minimal complexity.

While retailer ownership may not ensure that benefits are equitably shared with consumers, community retailers can have different incentives. For example, in the Yackandandah trial (see Section 2.5), the participating retailer (Indigo) operates as a social enterprise, sells energy exported by microgrid sites to others in the community at discounted rates, and returns 50% of profits to the community. New Zealand does have social enterprise retailers, but the sector is still in its early stages.

Community (third party) ownership of the battery is possible but is unlikely to be economically viable in the short term.

Revenue from energy arbitrage[36] alone is not currently sufficient to support the capital investment required to install a battery. As noted above, a solid economic case requires revenues from providing other services. As technology costs come down, energy arbitrage may become sufficient, but network services applications are a much bigger potential benefit pool[37]. Standalone community

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[36] In this context, energy arbitrage involves the retailer charging the battery when spot prices are low or negative and discharging when prices are high.

[37] In 2023, Wellington Electricity estimated potential benefits of 2-300m of increased use of distribution network flexibility in Wellington alone.

battery projects will not be viable until technology costs reduce further, the value of time shifting energy increases (e.g., due to more cost-reflective network tariffs that result in greater benefits to consumers from shifting consumption to lower demand periods), or EDBs make progress in standardising and procuring non-wires services.