NEIGHBOURHOOD BATTERY INITIATIVE – FINAL REPORT

Prepared for: **Central Victorian Greenhouse Alliance**

Version 1.1 - 13 September 2022

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1 Executive Summary

1.1 Purpose of this report

The Central Victorian Greenhouse Alliance (**CVGA**) works across Central and Northern Victoria to support local government with climate change mitigation and adaptation activities.

CVGA received funding as part of the Neighbourhood Battery Initiative (NBI) program run by the Victorian State Government Department of Environment, Land, Water and Planning (**DELWP**) to investigate the feasibility of potential neighbourhood battery projects within their local government areas.

CVGA commissioned Orkestra to undertake a detailed analysis of the technical and economic feasibility of neighbourhood batteries and advise on technical, commercial and implementation project considerations.

1.2 About this report

This report is the final deliverable as part of this project. It's divided into two sections:

- **Part A - Analysis:** Outlines the findings of our technical and economic feasibility study of 118 transformers.
- **Part B - Neighbourhood Battery Handbook**: A supplementary report which outlines technical, economic, commercial and implementation considerations for CVGA. Designed to be accessible to other neighbourhood battery proponents.

1.3 Our analyses approach

Orkestra conducted a technical and economic analysis of prospective neighbourhood battery sites across 6 small Victorian communities: Clunes, Wheatsheaf, Glenlyon, Lyonville, Ballan, and Pomonal.

We modelled the feasibility of installing a neighbourhood battery at 118 transformers owned by Powercor, the local distributor, which services 2090 homes and 248 businesses, covering an estimated two-thirds of the population in these communities.

Using Orkestra's software, the sites were assessed for a range of battery system sizes, control profile regimes, and future solar uptake scenarios to determine how effectively a neighbourhood battery could present as a solution to meet key community drivers. In total, 11,640 hypothetical neighbourhood battery projects were simulated for a duration of 15 years.

1.4 Key findings, recommendations, and next steps.

This analysis uncovered 4 key findings:

Key finding 1: **The underlying issues identified by communities are real and backed up by the data**. Current grid reliability is relatively poor. Without change, desired community progress towards higher solar penetration and energy independence will be thwarted by network constraints.

Key finding 2: **Community batteries offer some benefits** and to a degree, can solve issues identified in communities.

Key finding 3: **No sites were found to be close to financially viable for the project developer**, when accounting for direct value capture.

Key finding 4: **No sites were found to be economically viable for the greater community**, when accounting for direct and indirect value capture.

Recommendation 1:

Do not proceed to the next stage of project development of a neighbourhood battery, unless grant funding makes the project financially viable.

Recommendation 2:

CVGA should explore alternative options to address network issues in their regions.

1.5 Next steps and alternatives to 'neighbourhood batteries'

We do not recommend that CVGA give up on resolving the serious issues identified. To move towards a 100% renewable grid with high local solar PV uptake and local economic and grid resilience, the issues still need to be addressed.

However, in Australia today, other project types are more likely to offer viable and easy-to-deliver solutions which respond to some, or most, of the community drivers identified:

Suggestion 1: Pursue investigation of community battery projects with a broader definition

- Co-location of a community battery at a behind-the-meter C&I facility

- Community battery servicing a high-value community needs, for example, an emergency community shelter
- A community-led virtual power plant for residential batteries.
- Co-location of a battery at a community generator (for example Hepburn Wind).
- With the support of distributors, find project locations where additional network benefits can be realised beyond the transformer level.

In all cases, the business case will be enhanced if distributors are an active stakeholder and share a proportion of value captured with project proponents.

Suggestion 2: Advocate for non-battery solutions to the identified issues

CVGA is well placed to lobby governments, local distributors, and regulators for more action in dealing with the locally identified issues:

- Advocate for network upgrades related to solar carrying capacity, voltage rise issues, and grid resilience.
- Advocate for longer term network activities or market reforms which support local solar uptake, such as: Dynamic operating envelopes and dynamic export, local energy trading or cost-reflective network charges for locally produced energy Introduction

2 Introduction

2.1 Project background

The Neighbourhood Battery Initiative (NBI) is a $10.92 million grant program run by the Victorian State Government Department of Environment, Land, Water and Planning (**DELWP**) that supports trials of a range of neighbourhood battery models in Victoria, from feasibility to implementation. The Initiative will strengthen our understanding of the role neighbourhood scale batteries can play in Victoria's transitioning electricity system.

The NBI offered two streams of funding:

1) **Stream one** – funding to support project development, feasibility studies and business case developing
2) **Stream two** – funding to support implementation ready projects

This report was funded as a stream one project.

2.2 Project stakeholders

2.2.1 Central Victorian Greenhouse Alliance

The Central Victorian Greenhouse Alliance (**CVGA**) works across Central and Northern Victoria to support local government with climate change mitigation and adaptation activities. They represent 13 councils and help them to develop and implement innovative regional initiatives to benefit their local communities and the economy.

Since CVGA's launch in 2001, the Alliance has facilitated numerous large-scale projects, and these continue to have a positive impact in the community. Over the past five years, the Alliance has led projects worth over $50m in CVGA's region. They advocate on behalf of our member councils to ensure the voice of local government is heard strongly in state and federal policy settings.

CVGA, in partnership with Hepburn Wind and the shires and cities of Hepburn, Ballarat, Bendigo, Central Goldfields, Macedon Ranges, Swan Hill and Mildura recently received funding through the Victorian State Governments' Neighbourhood Battery Initiative (NBI) to undertake a feasibility study of neighbourhood batteries of at least 5 sites in the Hepburn Shire Region. Orkestra ultimately extended the scope to look at projects in 118 potential sites.

This report is the final deliverable to CVGA for their project funded by the NBI.

2.2.2 Project steering group

A project steering group was assembled to administer and guide the project, and support in community selection and data retrieval.

The steering group comprised of representatives from:

- CVGA (group leader)
- Hepburn Wind
- Hepburn Shire Council

2.2.3 Orkestra

Orkestra is responsible for conducting the technical & financial analysis of the project and writing this report. In addition, a 12-month license to use the Orkestra software for project feasibility has been provided to CVGA and associated network organisations as part of this project.

Established in 2021 as a spin-off from energy and management consultancy, New Energy Ventures, Orkestra are energy technology feasibility modelling specialists and are deep domain experts in batteries and virtual power plants.

Orkestra's **online planning software** enables project developers (such as community organisations, solar EPCs, energy retailers, virtual power plant proponents etc) to easily undertake feasibility modelling of simple to complex new energy projects - including solar, batteries, virtual power plants, electric vehicle chargers and more. The analysis presented here, where over 10,000 hypothetical projects were simulated, was only made possible by Orkestra's software using the batch simulation feature.

In the last 3 years, Orkestra has undertaken battery project modelling and consulting services for over 40 clients, many of whom are 'tier one' leaders in their field be it energy retail, solar, finance, or aggregation services. Through these engagements, Orkestra developed a deep understanding of the regulatory and commercial models for batteries and VPPs and have become a leading authority in the sector.

2.2.4 Other stakeholders

We'd like to thank other stakeholders for supporting the project, including:

- C4NET, for supporting with data retrieval from Powercor
- Powercor, for the provision of network data

2.3 About this report

2.3.1 Purpose

This report is intended to address the requirements for both CVGA and its partners, and DELWPs requirements under the NBI, specifically:

1. To support CVGA and its partners to decide on whether to proceed with a neighbourhood battery project, and if yes, what are the recommended project(s), and
2. To provide insights into neighbourhood batteries more generally for DELWP.

For CVGA, the purpose of the report is to:

- Support CVGA and its partners to decide on whether to invest in a neighbourhood battery project
- Determine a suitable location for a neighbourhood battery
- Provide a recommendation on a business model for a neighbourhood battery and determine which stakeholders should be involved
- Establish what is the "best" neighbourhood battery value stack and provide framing for what is the "best" neighbourhood battery project
- Highlight the risks and obstacles to the deployment of a neighbourhood battery.

For DELWP, the purpose of this report is to:

- Support understanding of the full range of benefits that neighbourhood scale batteries can provide
- Help to overcome barriers to the deployment of neighbourhood scale batteries
- Inform regulatory reform
- Determine which methods of neighbourhood scale battery deployment provide the most benefits for the Victorian electricity system; and
- Support the decarbonisation of Victoria's electricity system to tackle climate change.

2.3.2 Structure

We have structured this report in the following way:

Part A: Analysis

In this section of the report, we present our technical and economic analysis of prospective neighbourhood battery sites across 6 small Victorian communities: Clunes, Wheatsheaf, Glenlyon, Lyonville, Ballan, and Pomonal.

We modelled the feasibility of installing a neighbourhood battery at 118 transformers owned by Powercor, the local distributor, which services 2090 homes and 248 businesses, covering an estimated two-thirds of the population in these communities.

In total, across the 118 sites we assessed 11,640 hypothetical neighbourhood battery projects for the following potential benefits:

- Improved energy independence
- Improved solar hosting capacity of transformers
- Provision of back-up power
- Direct financial benefits to the project owners, and (where possible to estimate)
- Indirect financial benefits to the community, distributor, or the environment.

Here we answer questions, such as: do neighbourhood batteries 'make sense' today, and/or in the future? What benefits do they bring? What challenges do they face?

To answer these questions, we unpack insights from the data and bring tangible examples to life using case studies. We also recommend the best projects for each community, and best battery sizes and control algorithms for neighbourhood batteries.

Part B: Neighbourhood Battery Handbook

This section provides important background information for a proponent considering the development of any neighbourhood battery project. Whilst written to support the CVGA brief, we have intended to write a stand-alone section of the document which can be read by other community organisations in Australia.

In Part B we:

- Introduce the concept of neighbourhood batteries, including how to think about their benefits and costs.
- Outline the key practical considerations a neighbourhood battery project including the technical, commercial, and operational aspects.
- Discuss what defines a successful neighbourhood battery
- Discuss potential cost-effective alternatives to neighbourhood batteries

The Handbook section is designed to be read by any proponent of neighbourhood batteries. It is, of course, written for and informed by the primary research undertaken in Part A, and contains important prior knowledge for interpreting the Analysis. As such, the two sections could be read in reverse (recommended if your understanding of community batteries is elementary), or at a minimum, read in parallel, whereby the reader refers to Part B as required and as directed from Part A.

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Neighbourhood Battery Initiative
Final report

PART A: ANALYSIS

3 Summary of the analysis

Orkestra conducted a technical and economic analysis of prospective neighbourhood battery sites across 6 small Victorian communities: Clunes, Wheatsheaf, Glenlyon, Lyonville, Ballan, and Pomonal.

We modelled the feasibility of installing a neighbourhood battery at 118 transformers owned by Powercor, the local distributor, which services 2090 homes and 248 businesses, covering an estimated two-thirds of the population in these communities.

Using Orkestra's software, the sites were assessed for a range of battery system sizes, control profile regimes, and future solar uptake scenarios to determine how effectively a neighbourhood battery could present as a solution to meet key community drivers. In total, 11,640 hypothetical neighbourhood battery projects were simulated for a duration of 15 years.

3.1 Key findings, our recommendation, and next steps.

This analysis uncovered 4 key findings:

Key finding 1: **The underlying issues identified by communities are real and backed up by the data**. Current grid reliability is relatively poor. Without change, desired community progress towards higher solar penetration and energy independence will be thwarted by network constraints.

Key finding 2: **Community batteries offer some benefits** and to a degree, can solve issues identified in communities.

Key finding 3: **No sites were found to be close to financially viable for the project developer**, when accounting for direct value capture.

Key finding 4: **No sites were found to be economically viable for the greater community**, when accounting for direct and indirect value capture.

Recommendation 1:

Do not proceed to the next stage of project development of a neighbourhood battery, unless grant funding makes the project financially viable.

Recommendation 2:

CVGA should explore alternative options to address network issues in their regions.

The results present a mixed picture for the neighbourhood batteries assessed. On one hand, there is a real need for a solution, and the batteries were able to respond effectively to meet some community drivers. However, ultimately the projects struggled to achieve both financial and economic viability. The results raise questions about whether relatively small grid-connected battery projects within the distribution network are suitable at all.

As shown in Figure 1 below, even the "best project found" fell well short of providing sufficient direct financial and indirect economic benefits to warrant the project proceeding.

It must be noted that our analysis was limited by the data available, meaning that the provision of soft network capacity is the only network issue we could assess a solution for. Powercor may well have local power quality issues present, potentially warranting a higher value placed on certain neighbourhood battery locations and solutions than modelled here.

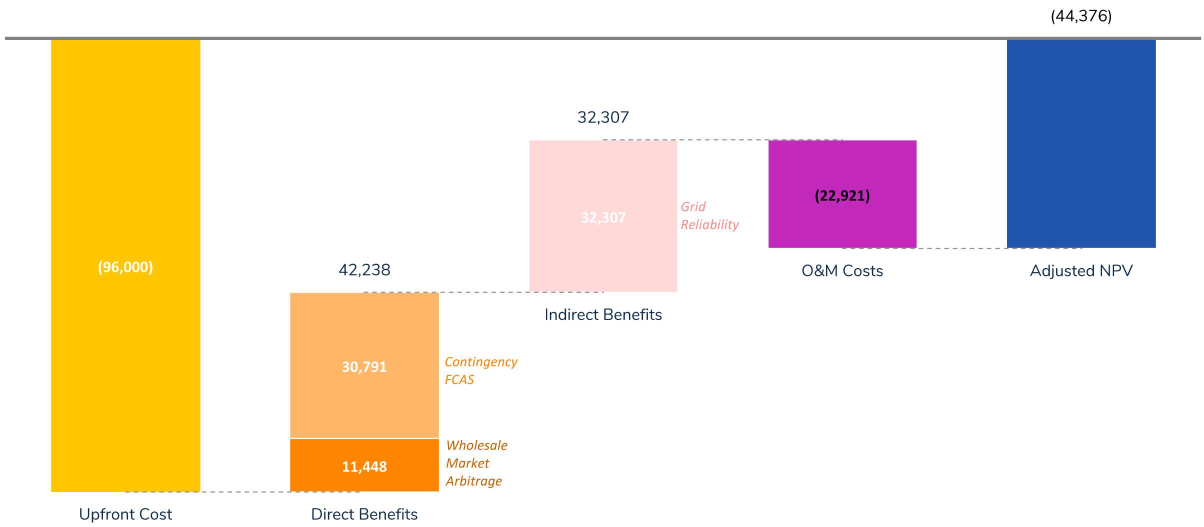

Figure 1 – Waterfall chart of the "best project" determined to have the highest economic benefit. This project was for a 500kVA transformer in Ballan with 8 homes and 1 business connected to it. The project selected was a 120-kWh battery with an optimisation control algorithm enabling it to provide wholesale market arbitrage and contingency FCAS while also providing improved grid reliability

3.2 What might change this recommendation in the future?

Several factors in the future may warrant a reconsideration of community batteries for the sites in question, for example:

Improved participation from distributors:

1. DNSP identification of additional high value network issues which are not covered in this analysis; combined with
2. Improved incentives from the DNSP for community battery proponents via:
    a. Network support payments for battery services to the network
    b. Release of a more attractive network tariff for community batteries

Changing market or regulatory factors (discussed in 8.1) such as:

1. Increasing market prices and volatility
2. Additional value streams coming online
3. Substantial reduction in battery upfront costs
4. Monetisation of grid reliability services, either via governments or from distribution

5. Energy market reform which would enable local energy trading (i.e., discounted network wheeling charges) and vastly improve economics for street/transformer scale “shared battery as a service” business models. Note, a rule change request has already been rejected for this and is unlikely to get up again any time soon. See discussion in Appendix C - Commercial and regulatory challenges for “shared battery as a service”.

3.3 What about government incentives for batteries?

Government incentives, such as those currently being considered by the Federal Government and the Tranche 3 funding of the Neighbourhood Battery Initiative (NBI) funding may ensure potentially all the projects in this report financially breakeven for the project proponents. In Section 10 we clearly outline the amount of grant funding required for the ‘best’ projects in each township to financially breakeven.

3.4 Suggested next steps and alternatives to ‘neighbourhood batteries’

We do not recommend that CVGA give up on resolving the serious issues identified. To move towards a 100% renewable grid with high local solar PV uptake and local economic and grid resilience, the issues still need to be addressed.

However, in Australia today, other project types are more likely to offer viable and easy-to-deliver solutions which respond to some, or most, of the community drivers identified:

Suggestion 1: Pursue investigation of community battery projects with a broader definition

The NBI definition of a neighbourhood battery is limiting – specifically requiring projects to be connected front-of-the-meter rather than co-located with loads or generators – and thus prevents the unlocking of higher value battery use cases. There is an opportunity to create community battery projects that service community and network goals, but tap a richer, more robust value stack available to battery projects sited at different connection points.

Examples of more attractive community battery projects could include:

- **Co-location of a community battery at a behind-the-meter C&I facility** (for example, the Yak01 battery by Totally Renewable Yackandandah). C&I projects are more likely to reach viability when tariffs feature a peak demand charge and additional energy arbitrage opportunities are present. Ideally, located in a constrained network area to support solar hosting capacity, and oversize solar installation versus the requirements of the load to create energy independence gains.
- **Community battery servicing a high-value community needs**, for example, a solar and battery powered emergency shelter, which could also provide market or network benefits on a day-to-day basis.
- **A community-led virtual power plant for residential batteries**. Residential batteries are close to economic for high energy users with oversized solar on time-of-use tariffs. These batteries also serve community needs by improving energy independence, increasing the solar hosting capacity of the network, and back-up power provision is easier and cheaper at the home than at the transformer level.
- **Co-location of a battery at a community generator** (for example Hepburn Wind). Such batteries can tap arbitrage opportunities and provide soft-network capacity to the generator, whilst meeting community goals of energy independence. They may also achieve economies of scale for a standalone project, whereas a neighbourhood battery might struggle.

In all cases, the business case will be enhanced if distributors are involved and, share a proportion of value captured with project proponents.

Suggestion 2: Advocate for non-battery solutions to the identified issues

CVGA is well placed to lobby governments, local distributors, and regulators for more action in dealing with the locally identified issues.

- **Advocate for network upgrades** which will very likely be much lower cost than battery storage and meet certain community drivers related to solar carrying capacity, voltage rise issues, and grid resilience. We would strongly recommend that CVGA explore this more intensively with Powercor.

- **Advocate for longer term network activities or market reforms which support local solar uptake,** such as:
    - Dynamic operating envelopes and dynamic export limits enable a more nuanced approach to limiting solar PV in constrained areas of the grid in the future
    - Local energy trading or even simply a more cost-reflective network charges for locally produced energy could unlock the virtual battery-as-a-service-model at the street / transformer scale, providing a viable alternative to residential storage.

4 Analysis approach

4.1 Identifying the key drivers for neighbourhood batteries

It's clear from anecdotal evidence that there is strong desire for neighbourhood batteries in the regional communities with which we are working - and in the broader community energy sector.

However, it is only by understanding the drivers that we can make an objective assessment of whether a neighbourhood battery can present a suitable solution to meet these drivers.

As such, the first step in our analysis was to confirm the key community drivers for a neighbourhood battery. Several methods were used to understand and prioritise drivers:

- Firstly, a workshop was held with the project steering group.
- Additionally, members of the project steering group conducted a survey to understand drivers for a neighbourhood battery.

Ultimately, the project steering group have determined the main drivers for a neighbourhood battery, in rough order of priority, to be:

- **Increasing the energy independence** of communities.
- **Unlocking more solar on low voltage distribution networks** that are increasingly constrained by too much solar export.
- **Improving local grid reliability** by reducing the frequency and severity of grid outages.
- **Unlocking new economic value** for individuals and communities, in part to help manage energy affordability.

4.2 The 5 key questions we attempt to answer

We have structured our analysis by posing 5 key questions which we have answered in sequential order in the next chapter. They are:

1. **Is there an underlying need for neighbourhood batteries today?** To answer this, we first conducted a baseline data analysis of how each transformer was tracking against the identified drivers. This is both a reality check of the anecdotal evidence, and a data analysis to rank the severity of the issues and determine which transformers have the most pressing needs.

2. **Can neighbourhood batteries address community identified issues today?** How does a neighbourhood battery uplift key metrics against the baseline? Can they improve energy independence, solar hosting capacity, and grid resilience?

3. **Can neighbourhood batteries address community identified issues <u>in the</u> <u>future</u>?** We apply projections of different future uptake curves of solar PV in each transformer to understand if a) do the issues identified today get worse with more solar PV? And b) do neighbourhood batteries present a solution to enable higher local solar uptake, improve energy independence, and increase grid resilience?

4. **Are neighbourhood batteries <u>financially viable,</u> either today or in the future?** Can a project developer (be it a community organisation or private enterprise) achieve a positive return on investment based on direct value capture alone?

5. **Are neighbourhood batteries <u>economically viable</u>, either today or in the future?** Can a project provide a positive return on investment to the broader community, when accounting for direct and indirect benefits which flow to a range of stakeholders? We do a detailed cost-benefit analysis to find out.

Along the way we were also able to answer a couple of 'bonus' questions such as:

1. **<u>What is the ideal control profile</u> for a neighbourhood battery?** How important is the selection the batteries control algorithm and associated value stack in balancing the competing project needs and ultimately achieving project success?

2. **<u>Does size matter</u> for a neighbourhood battery?** How important is size of a community battery in determining project success?

4.3 Selection of sites for analysis

Orkestra worked with CVGA, Hepburn Wind and Hepburn Shire Council to identify 4 areas in the Hepburn Shire – Wheatsheaf, Clunes, Glenlyon, Lyonville, that have been experiencing various network issues and that correlate with Powercor as areas of high interest through the Z-NET process. In addition, 2 sites of Ballan and Pomonal were attached to the project via the Community Power Hub program.

Network issues included being unable to gain connection for a rooftop solar installation or experiencing grid reliability issues (i.e., regular blackouts). Other lower priorities issues identified included voltage rise which was known to affect certain areas, which can lead to solar PV systems being curtailed.1 [1]

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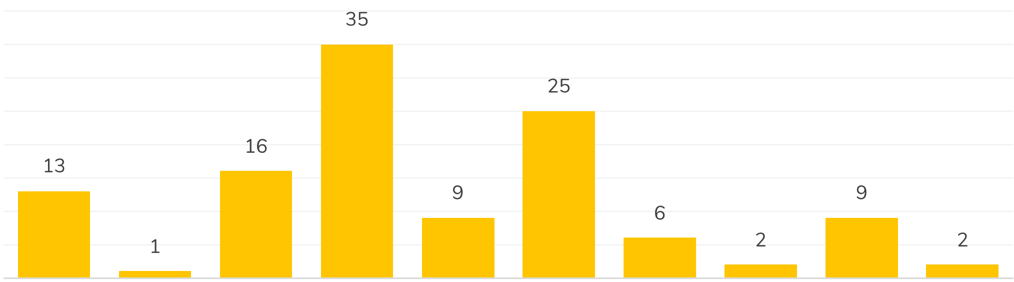
[1] Owing to the inherent complexity and data requirements of modelling voltage rise within a network, assessment of this network issue was not pursued as part of this project.

Orkestra and CVGA worked with C4NET to obtain the requisite data to enable battery analysis for all the transformers within these communities. For a total of 765 transformers, the following information was able to be obtained:

- 12-months of half-hourly load profile data (import and export)
- Transformer nameplate ratings (kVA)
- Number of customer connections per transformer – segmented into residential, commercial, and agricultural
- Number of solar connections per transformer

Filtering out for transformers with less than four connections, and transformers with data quality issues, a final list of 118 transformers proceeded to the analysis stage.

The breakdown of customers and transformers by nameplate rating is shown in Figure below. In general, we would describe the transformers within the fleet as relatively small, with 84% of transformers of a size 100kVA or less. To provide context for this assessment, a typical transformer in dense urban areas would be 500kVA.



Township	10 kVA	20 kVA	25 kVA	50 kVA	63 kVA	100 kVA	200 kVA	300 kVA	315 kVA	500 kVA	Total
BALLAN	3	0	2	21	3	8	6	2	4	2	51
CLUNES	3	0	6	6	3	7	0	0	5	0	30
GLENLYON	0	0	3	2	2	1	0	0	0	0	8
LYONVILLE	4	0	1	2	1	1	0	0	0	0	9
POMONAL	2	1	3	3	0	0	0	0	0	0	9
WHEATSHEAF	1	0	1	1	0	8	0	0	0	0	11
Total	13	1	16	35	9	25	6	2	9	2	118

Figure 2– Breakdown of transformers assessed in Orkestra's analysis by village and transformer size.

The 118 transformers service a total of:

- 2090 homes and 248 businesses
- 550 residential solar and 40 commercial solar systems

This accounts for an estimated 64% of connections in the communities considered, according to our analysis of the data provided by Powercor.

4.4 Key assumptions used in construction of hypothetical projects

For each transformer we considered 5 solar scenarios, 5 battery sizes and 4 control profiles, which resulted in 100 different variations of project configuration for each site (5 x 5 x 4 = 100).

Table 1 - Input scenarios for each site

<table>
<tr><td rowspan="2">5 x Solar scenarios</td><td>Current solar uptake</td><td>40% uptake</td><td>60% uptake</td><td>80% uptake</td><td>100% uptake</td></tr>
<tr><td colspan="5">Uptake assumes an average of 6.6kWp/5kW per residential dwelling and 19.8kWp / 15kW per non-residential dwelling.</td></tr>
<tr><td rowspan="2">5 x Battery sizes</td><td>No battery</td><td>120kWh / 36kW</td><td>240kWh / 72kW</td><td>480kWh / 144kW</td><td>960kWh / 288kW</td></tr>
<tr><td colspan="5">At the request of the project steering group, all battery technology is li-ion and based on the modular size of Relectrify batteries (3.33 hr duration).</td></tr>
<tr><td rowspan="2">4 x Control profiles</td><td>Solar charging</td><td>Delayed solar charging</td><td>Delayed solar charging w/ market triggers.</td><td colspan="2">Optimisation</td></tr>
<tr><td colspan="5">See 4.6.4 for detailed information on control profiles and associated value stacks.</td></tr>
</table>

We applied the 100 variants to each of the 118 sites, resulting in 11,800 hypothetical projects. We then filtered out irrelevant projects where the current solar uptake already exceeded the future solar uptake threshold, resulting in 11,640 hypothetical projects.

4.5 What we assessed

For each of the 11,640 hypothetical projects, we assessed the following:

- **15-year simulation of solar and battery activity** in 30-minute increments. This considered solar and battery capacity degradation and tariff and market price escalation over the project life.
- **15-year NPV and IRR outcomes** for the battery based on the future revenues and costs of the various services.
- **Energy independence** by transformer at the current solar uptake and for future penetrations, calculating the net improvement of a battery. (See Figure 32 below in Appendix A for more details.)

- **Calculation of soft network capacity** determined as the maximum export (in kW) from transformer with no battery installed versus the maximum export from the transformer with batteries installed. (See Figure 32 in Appendix A for more details.)

We then undertook a subsequent analysis to investigate the **back-up power potential** of neighbourhood batteries, should a random grid outage occur[2]. This analysis was completed for a select number of transformers (the recommended 'best' project in each community).

Fun fact regarding this analysis

174,600 years of interval-grade battery activity was simulated across all projects (that's **3,058,992,000** half-hour energy intervals)

This took only **37 minutes** for **Orkestra's software** to compute, leveraging hundreds of cloud computers in parallel. On a personal computer, this would have taken 5 days of computational time.

4.6 How the modelled projects earn revenue

4.6.1 Direct value streams assessed

Direct value capture earning options are limited for a relatively small, front-of-the-meter neighbourhood battery. This is particularly the case in our analysis, where we are assessing a third party (i.e., non-distributor) owned and operated project in the absence of a demand response program or negotiated revenue stream from a co-operating distributor. As such, we're left with only a few means to reliably earn revenue via direct value capture:

- Network tariff arbitrage
- Wholesale spot arbitrage:
- Contingency FCAS

[2] The back-up power analysis has not assessed any detailed network requirements or costs to support grid islanding during an outage. As such, the back-up power analysis needs to be considered as an exploration of the potential of this benefit, and not a detailed technical assessment.

4.6.2 Indirect value streams assessed

Although not counted as 'revenue' in a traditional approach (i.e., direct value capture), in this analysis we estimated the value received by indirect value capture. This is additional value that flows to the network, community, and individuals in the form of:

- Soft network capacity value to the network
- Soft network capacity value to individuals serviced by transformer (who can install solar due to increased solar hosting capacity)
- Energy independence value
- Grid reliability value

Methodologies and calculations for these indirect value streams are outlined in Section 9.

4.6.3 Tariffs

We've assumed the same set of tariffs for all projects[3]: For network tariffs, we've used the Powercor community battery trial tariff which mildly incentivises discharging but heavily penalises charging at peak times. For retail tariffs, we've used a wholesale spot exposed tariff (akin to a Flow Power tariff).

4.6.4 Control profiles

As the tariff are identical for all projects, it is left to the battery control profiles to determine how - and how much - revenue is captured:

- Control profiles 1 & 2 (Solar charging & delayed solar charging) respond only to solar and load. Whilst this will maximise energy independence, any financial value captured is due to incidental arbitrage of the network and wholesale retail tariff.
- Control profile 3 adds market triggers to the base activity of delayed solar charging. As such, the battery will intentionally respond to wholesale and FCAS revenue opportunities, but network tariff arbitrage is still incidental to the battery activity.
- It is only Control Profile 4 (Optimisation) which has full visibility of the range of value on offer and intentionally chases the highest potential earnings. The downside is that any capturing of indirect non-monetary value streams (i.e., energy independence) is entirely incidental.

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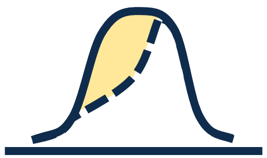
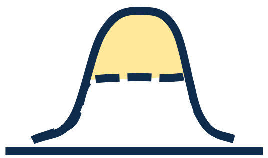
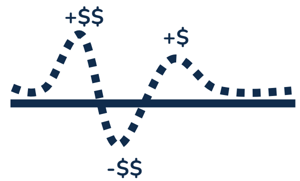
Full tariff details are in Appendix B, Table 22 and Table 23

The four control profiles are explained in detail in Table 2. This table also introduces some of the trade-offs for a neighbourhood battery as they relate to the various control strategies.

Table 2 – Description and benefits of the control profiles considered in this report

Maximised energy independence ⟵⟶ **Maximised economic return**

Control profile	1. Solar charging	2. Delayed solar charging	3. Delayed solar charging + market triggers	4. Optimization
Illustration				
Description	Battery attempts to store energy whenever there are negative energy flows at the transformer (i.e., generation of energy exceeds the load). Battery does not explicitly chase value capture. Any financial value capture is incidental.	Same as control profile 1 but charge only commences at a predefined time of day to increase the chance of charging during times of peak export. Battery does not explicitly chase value capture. Any financial value capture is incidental.	Same as control profile 2 but: • If the wholesale market price exceeds $1000 then force the battery to discharge. • If the wholesale market price dips below $0 then force the battery to charge. • If the FCAS price exceeds $100 then the battery should stop all activity in case of dispatch.	Linear optimization of charging and discharging of the battery over a forward 48-hour period as optimized to charge during times of low prices and discharge during times of high prices. The value stack for this control profile was wholesale market arbitrage and FCAS with capacity of the battery reserved to participate in the FCAS market.
Benefits	• Improve **energy independence** of the residents and businesses connected to a particular transformer.	• As per control profile 1 • **Potentially improved soft network capacity provision** by better aligning the battery charging with times of peak export.	• As per control profile 2 • **Potentially improved economic performance from wholesale market participation** but with tradeoffs against energy ind. and network support.	• **Optimal charging and discharging of the battery for maximum economic benefit** • **Optimal for back-up power as the battery tends to be fully charged all the time.**

orkestra

5 Is there an underlying need for neighbourhood batteries?

Short Answer: **Potentially, yes.**

Anecdotal evidence from CVGA and their partners suggested that the community is having issues with their network, specifically regarding the inability to connect new solar systems (i.e., lack of solar hosting capability at the local transformers) and grid reliability.

Our analysis of the interval data provided by Powercor backs up the anecdotal evidence. It suggests that there are issues among the transformers assessed that *could potentially* be resolved by a battery.[4]

- **14% of transformers are at or near their solar hosting capacity.** This could already be a barrier to a home or business installing solar. Hosting capacity issues are largely confined to small transformers (10kVA to 50kVA in size)
- **The weighted average energy independence was found to be 24%** - still a long way shy of 100% potential maximum.
- **The average extended grid outage was found to be 8 hours +/- 0.5 hours over a 12-month period.** It must be noted that, several transformers experienced prolonged outages much longer than this.

5.1 Solar hosting capacity (baseline assessment)

Baseline assessment: **Not a disaster (yet), but room for improvement**

Figure 3below shows the percentage of transformers at or near their maximum solar hosting capacity based on our estimations of solar currently installed. Of the 118 transformers assessed in detail, 14% (17 transformers impacting 117 residential customers) are currently at or near capacity, meaning that Powercor will likely reject a connection request issued by customers connected to these transformers[5]. However, as we can see from the chart, hosting capacity issues mostly occurs when transformers are relatively very small.

[4] We can't be definitive as this would require Powercor's confirmation and more detailed data and analysis.

[5] Powercor will likely assess the solar hosting capacity by summing the capacity of all invertors [kVA] connected to the transformer and compare this to the transformer size [also kVA]. We have considered a transformer at or near capacity if the transformer capacity would be exceeded if an additional 10kVA of inverter capacity were connected to the transformer.

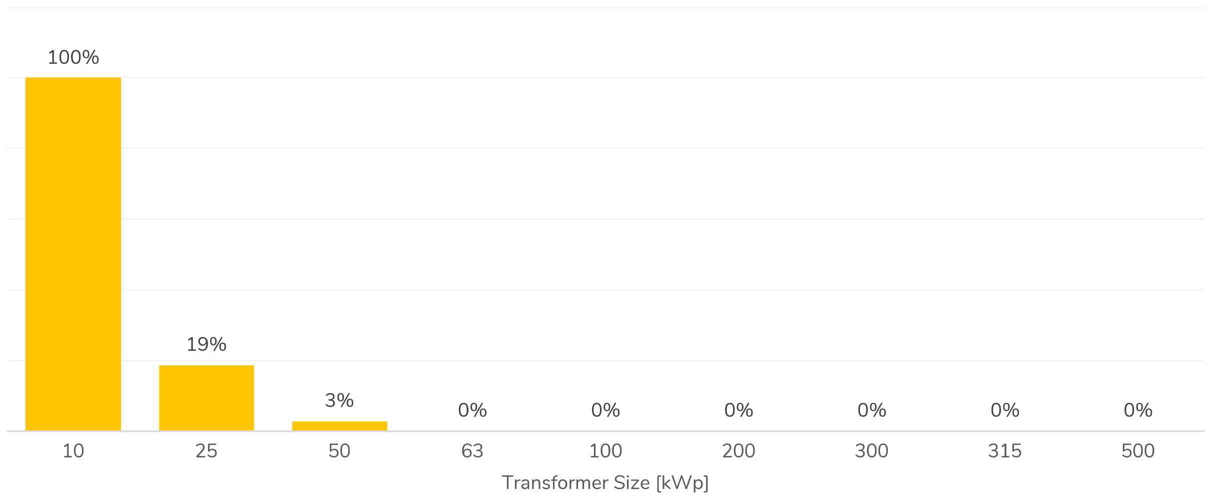


Figure 3- Percentage of transformers at maximum solar hosting capacity.

5.2 Energy independence (baseline assessment)

Baseline assessment: Could be improved but limited potential at current solar uptake

Moving on to energy independence, we assessed the current energy independence by transformer. Energy independence is the percentage of energy supplied locally, in this case by solar. **Energy independence was determined to have a range of 4% to 71% across the 118 transformers with the weighted average being 24%.**

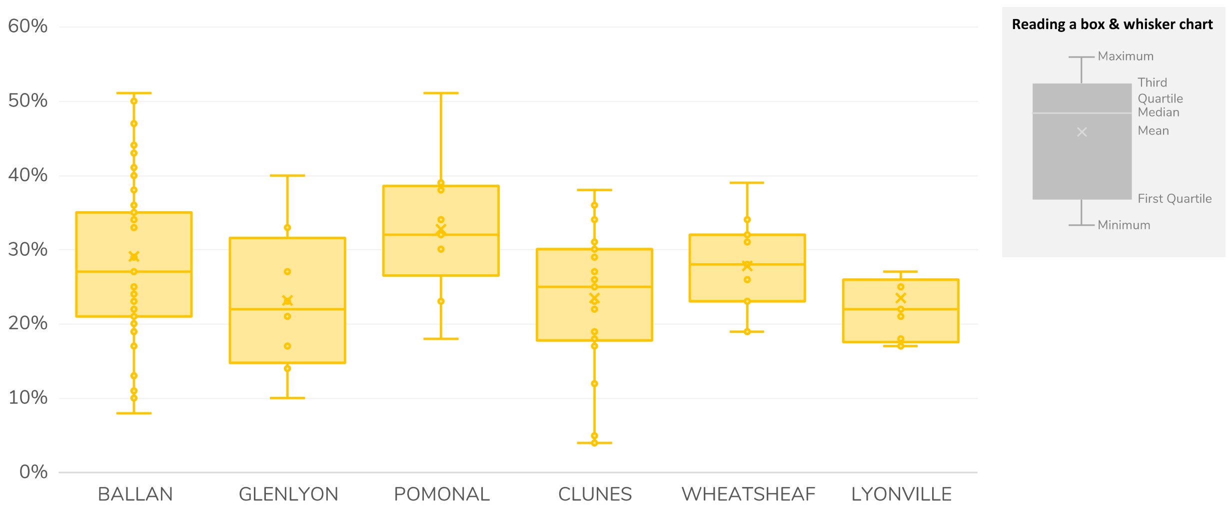


Figure 4- Spread of energy independence for transformers by village.

However, if you look at the solar self-consumption – the measure of how much of the solar generation is used locally and not exported at the transformer – we estimate that 54% to 100% of the solar is being consumed locally and not exported, with the weighted average being 97%. Figure –5 below shows the weighted average by village.

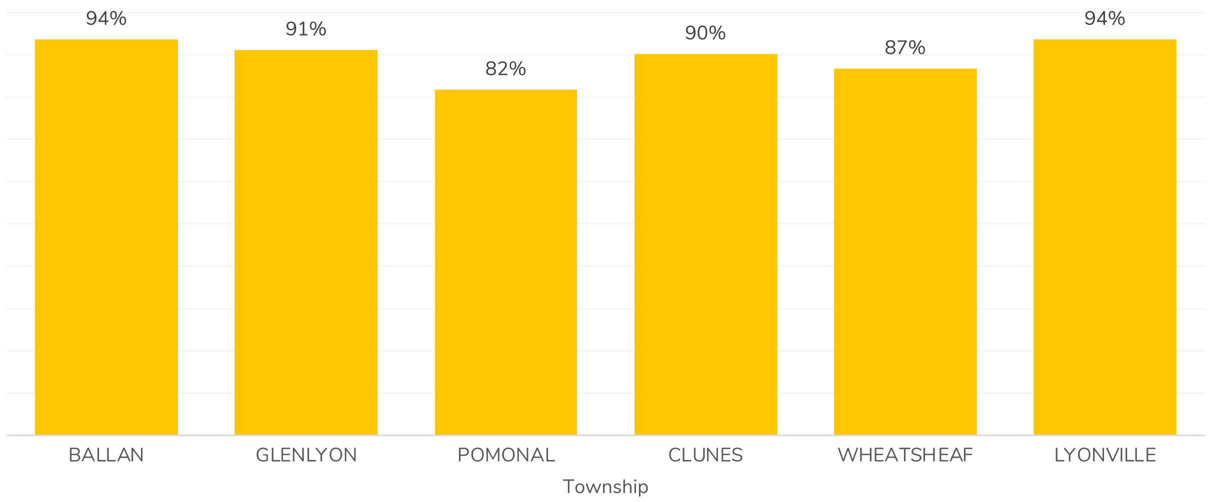


Figure –5 Estimated weighted average solar self-consumption by village

The impact of very high solar self-consumption is that, very little energy in aggregate is currently being exported from the transformers, meaning that the addition of a battery will unlikely do much to uplift energy independence.

In the next section, however, we explore a couple of outlier transformers with a low level of solar self-consumption, who in fact do see an uplift in energy independence.

5.3 Grid resilience (baseline assessment)

Baseline assessment: Relatively poor network reliability

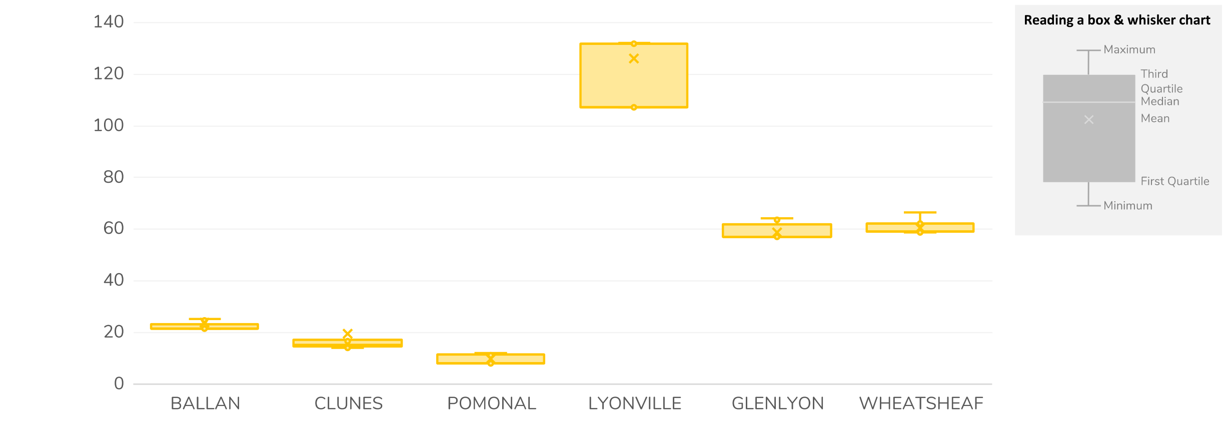
The average outage time is approximately 8 hours for all transformers. This equates to a grid uptime of 99.91%, which is well below the stated claim on the Powercor website of 99.97% availability[6], and relatively low by Australian standards.

Powercor's 2022/23 targets for unplanned outages are:

- 104.14 minutes (just under 2 hours) for short rural feeder lines.
- 240.14 minutes (4 hours) for long rural feeder lines.

[6] Powercor network reliability statistics (Source: Powercor website, 19/8/22)

It is fair to say that Powercor is falling well short of those targets in the locations assessed. Figure 6 shows the average extended grid outage time[7] in calendar year 2021 ranged from 9.6 hours in Pomonal to 125.8 hours (over 5 days of outages in total!) in Lyonville, with the longest continual outage being for 3 days.



Average outage time for 2021	23.8 hours	19.5 hours	9.6 hours	125.8 hours	58.7 hours	60.2 hours

Figure 6– Average extended grid outage time and spread by village for the transformers assessed.

Our analysis shows there were a total of 26 outage events across the villages. Of these, 21 events (approximately 80%) were less than or equal to 8 hours in length. This is captured in Table 3 below.

[7] To establish the extended grid outage time, we counted all the intervals in the transformer interval data provided by Powercor where the export volume and import volume [both in kWh] are both zero – i.e., there are no energy flows through the transformer. Due to the 30-minute resolution of the data, this approach:

- May not capture events less than an hour
- Will not capture any events less 30 minutes, and
- May underestimate the duration of an events witnessed in the data by up to 30 minutes.

Table 3 – Count of outage events, count of outage events less than 8 hours, average duration, and maximum duration by village by accessing one transformer for each village. “All towns” shows the statistics for all events excluding coincident events.

Village	Count of outage events	Count of events less than 8 hours	Average outage duration (hours)	Maximum outage duration (hours)
Ballan	4	2	6.8	11.5
Clunes	5	5	2.9	8.0
Pomonal	9	7	7.1	40.0
Lyonville	12	10	11.0	72.0
Glenlyon	2	2	4.0	6.5
Wheatsheaf	10	8	5.9	32.5
All towns	**26**	**21**	**7.8**	**72.0**

Box 1 - Case studies of a 25kVA transformer in Clunes with potential to improve solar hosting capacity

Below is an example of a transformer that is currently at capacity and may benefit from a neighbourhood battery to improve solar hosting capacity. This transformer was selected as a case study as it is currently constrained and not a 10 kVA transformer and therefore several customers are likely to be prevented from accessing solar (or at a minimum solar exports).

Item	Statistic
Transformer ID	20387758-BAN006
Village	Clunes
Transformer Size	25 kVA
Residential customers	10
Commercial customers	nil
Solar connections	5
Solar hosting capacity available?	No
Current energy independence	29%
Current solar self-consumption	94%

Box 2 - Case study of a 50kVA transformer Ballan with potential to improve its energy independence

Below is an example of a transformer that may benefit from a neighbourhood battery to improve energy independence and solar self-consumption. This transformer was selected as a case study as it has a relatively low percentage of solar self-consumption and good potential to improve energy independence.

Item	Statistic
Transformer ID	20383905-BMH003
Village Township	Ballan
Transformer Size	50 kVA
Residential customers	5
Commercial customers	nil
Solar connections	3
Solar hosting capacity available?	Yes
Current energy independence	29%
Current solar self-consumption	**50%**

6 Are neighbourhood batteries a solution for today?

Short answer: Neighbourhood batteries have some benefit but are a rather ineffective and expensive solution to the issues detected

Following on from our assessment of today's issues, we have assessed whether a neighbour battery can address today's issues of lack of solar hosting capacity, low energy independence, and grid reliability.

Our analysis showed that neighbour batteries:

1. Were able to improve the **solar hosting capacity** but only at 3 of 16 constrained transformers.
2. **Marginally improved energy independence** at current solar uptake levels, as most solar is already being absorbed by homes and businesses without solar installed on the same transformer, without needing a battery.
3. **Greatly improve the grid reliability** but is highly subject to the control algorithm selected.

We have provided case studies of two transformers to illustrate these points in **Box 3** and **Box 4**.

6.1 Do batteries improve solar hosting capacity today?

Outcome: Some uplift from battery, limited to only a few sites

The chart below shows the capability of various batteries to provide soft network capacity. Out of the 16 transformers at or near capacity today, only 3 transformers could be supported with a battery to improve their hosting capacity.

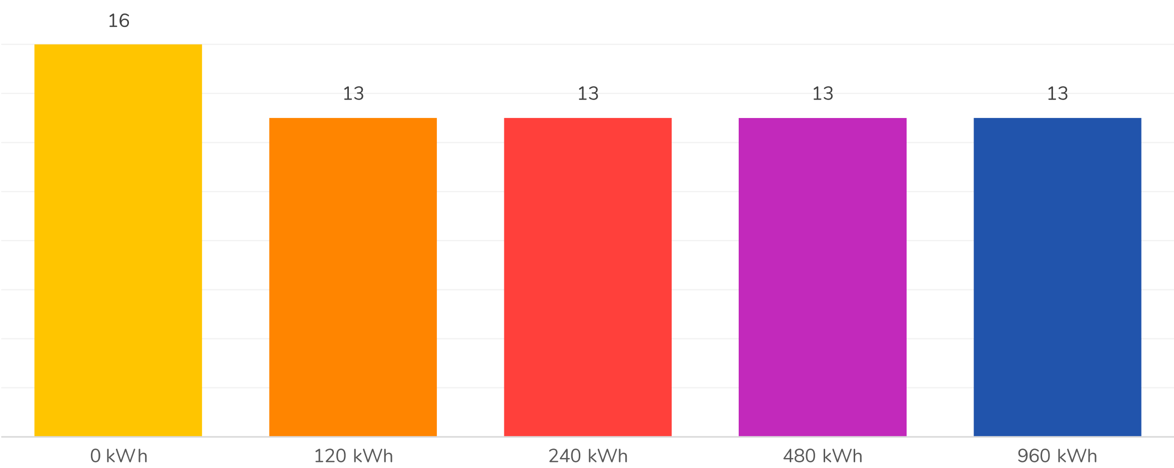


Figure 7 - Number of transformers at maximum solar carrying capacity by battery size given current solar uptake and using delayed solar charging control.

Box 3 provides a case study of one of the transformers that will benefit from a battery.

Box 3 - Case study of transformer benefitting from a neighbourhood battery improving solar hosting capacity at current solar uptake.

As discussed in Box 2 in the previous section, this Clunes transformer is currently at its maximum solar hosting capacity. We determined that a 36kW / 120kWh battery would provide soft network capacity of 12 kVA but at a total lifetime cost of $118k, even under optimistic assumptions. This would increase the solar uptake from 50% to 70%.

Neighbourhood Battery: Clunes							
Powercor Transformer ID	20387758-BAN006						
Transformer size	25 kVA						
Residential customers	10						
Commercial customers	nil						
Solar connections	5						
Technical specifications							
Battery size	36 kW / 120 kWh						
Control Profile	Rules based solar self-consumption with delayed start						
Value stack description	Soft network capacity, improved energy independence						
Financial summary							
15-year NPV Discount rate of 3%	($118k)						
Initial CAPEX	$96k						
Socials/environment benefits							
Solar connections enabled	2						
Est. soft network capacity	Before:	25kVA	After:	37kVA	**Uplift:**	**12kVA**
Est. solar hosting capacity	Before:	33kWp	After:	49kWp	**Uplift:**	**16kWp**
Est. energy independence at current solar uptake (36.4%)	Before:	29%	After:	33%	**Uplift**:	**4%**
Average percentage likelihood the battery can provide 8 hours of back up for any interval	0%						

Box 3 continued -Case study of transformer benefitting from a neighbourhood battery improving solar hosting capacity

Below gives further illustration on how a 36kW / 120kWh neighbourhood battery system can improve solar hosting by eliminating maximum export at midday. The chart shows the case of current solar uptake of 36.4% (in our modelling this was coined “pre-Solar” meaning pre additional solar).

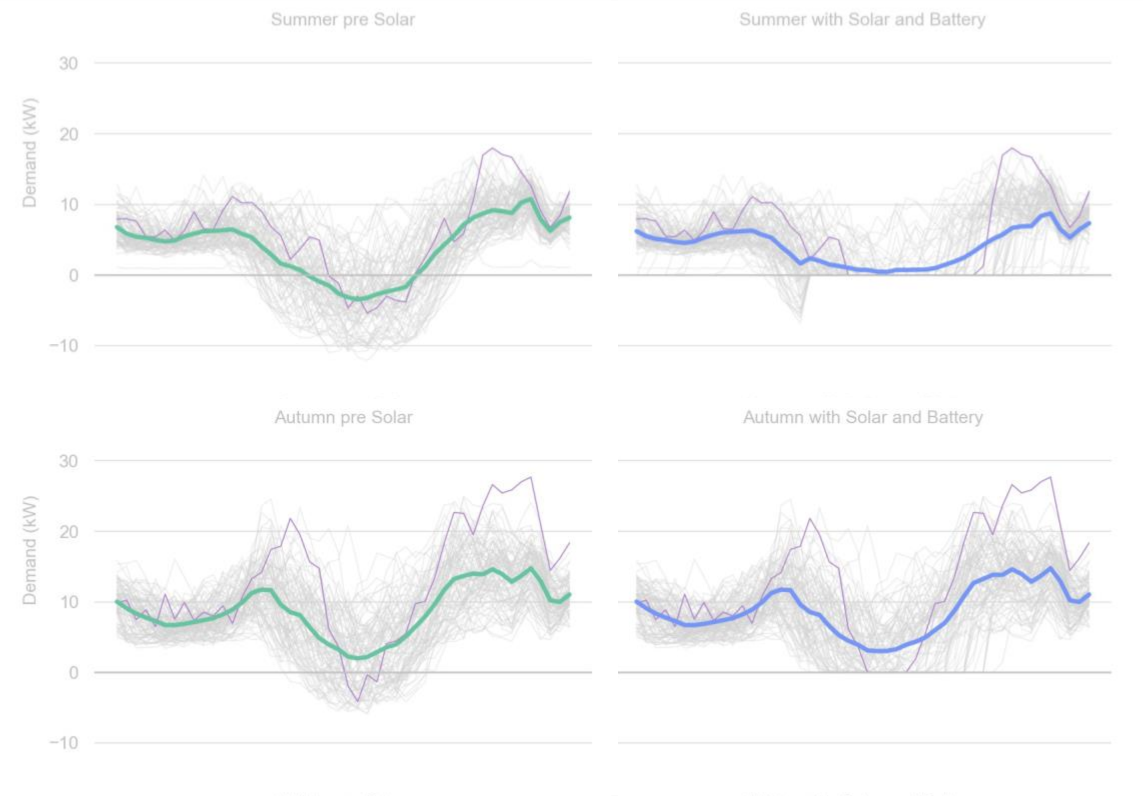


Figure 8 – Daily load profiles for transformer 20387758-BAN006 pre- and post-battery. Each grey line is one day of interval data for days within summer or winter. The solid blue lines show the average weekday. The dotted blue lines show the average weekend load. The purple line shows the maximum demand day.

6.2 Do batteries improve energy independence today?

Outcome: Only marginal improvements from batteries

The chart below shows there is little additional benefit by installing a neighbourhood battery for the purpose of improving energy independence based on the current solar uptake in the villages assessed. As discussed in Section 5.2, this is due to the factor that most solar generated is used by homes and businesses without solar installed, connected to the same transformer. **At most transformers, there simply isn't yet enough solar installed to achieve an uplift in energy independence.**

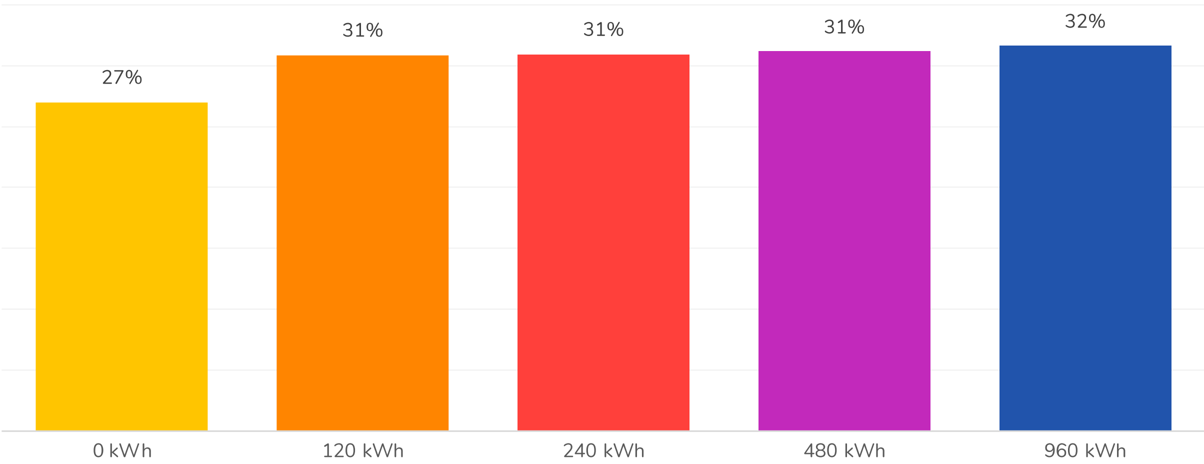


Figure 9- Average energy independence for all transformers by battery size for current solar uptake

Box 4 provides an example of one transformer with high solar uptake (47.3%) that would benefit significantly from a neighbourhood battery for the purposes of improving energy independence. However, the site is not a particularly good one for a neighbourhood battery as no other benefits were present.

Box 4 - Case study of transformer benefitting from a neighbourhood battery improving energy independence

Below is an example of a transformer that may benefit from a neighbourhood battery to improve energy independence and solar self-consumption.

Neighbourhood Battery: Ballan							
Powercor Transformer ID	20383905-BMH003						
Transformer size	50 kVA						
Residential customers	5						
Commercial customers	nil						
Solar connections	3						
Technical specifications							
Battery size	36 kW / 120 kWh						
Control Profile	Rules based solar self-consumption with delayed start						
Value stack description	Soft network capacity, improved energy independence						
Financial summary							
15-year NPV Discount rate of 3%	($117k)						
Initial CAPEX	$96k						
Socials/environment benefits							
Solar connections enabled	Nil (no capacity constraint)						
Est. soft network capacity	Before:	50kVA	After:	63kVa	**Uplift:**	**13kVA**	
Est. solar hosting capacity	Before:	66kWp	After:	84kWp	**Uplift:**	**18kWp**	
Est. energy independence at current solar uptake (47.3%)	Before:	29%	After:	55%	**Uplift:**	**26%**	
Est. energy independence at 100% solar uptake	Before:	37%	After:	87%	**Uplift:**	**50%**	
Average percentage likelihood the battery can provide 8 hours of back up for any interval	0%						

Box 4 continued - Case study of transformer benefitting from a neighbourhood battery improving energy independence

The figure below shows how a neighbourhood battery works to improve energy independence by storing solar energy and avoiding grid imports during times of net load. The figure also shows the challenge of achieving 100% energy independence as in winter there is insufficient generation to cover the load.

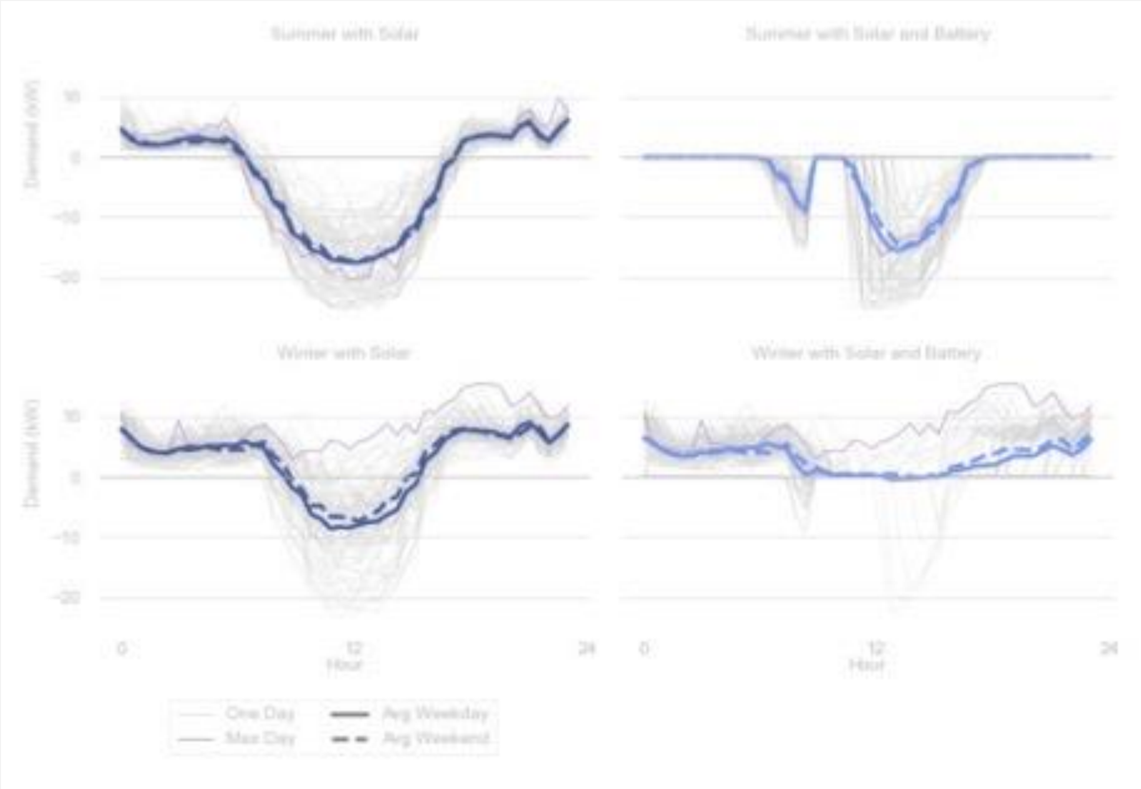


Figure 10 - Daily load profiles for transformer 20383905-BMH003 pre- and post-battery. Each grey line is one day of interval data for days within summer or winter. The solid blue lines show the average weekday. The dotted blue lines show the average weekend load. The purple line shows the maximum demand day.

6.3 Do batteries improve grid reliability issues today?

Outcome: Yes, but only when current solar uptake is high and large batteries are deployed.

The chart below shows the average percentage likelihood of providing 8 hours of back-up across various battery sizes and control algorithms for a 25kVA transformer. Our assessment suggests that transformers with a high solar uptake today will benefit significantly from a battery.

It's worth noting that this analysis assumes that in the event of a blackout, the transformer can isolate from the grid and the solar is permitted to continue to supply the local network even with the main grid down, and importantly able to synchronise with the grid upon reconnection.

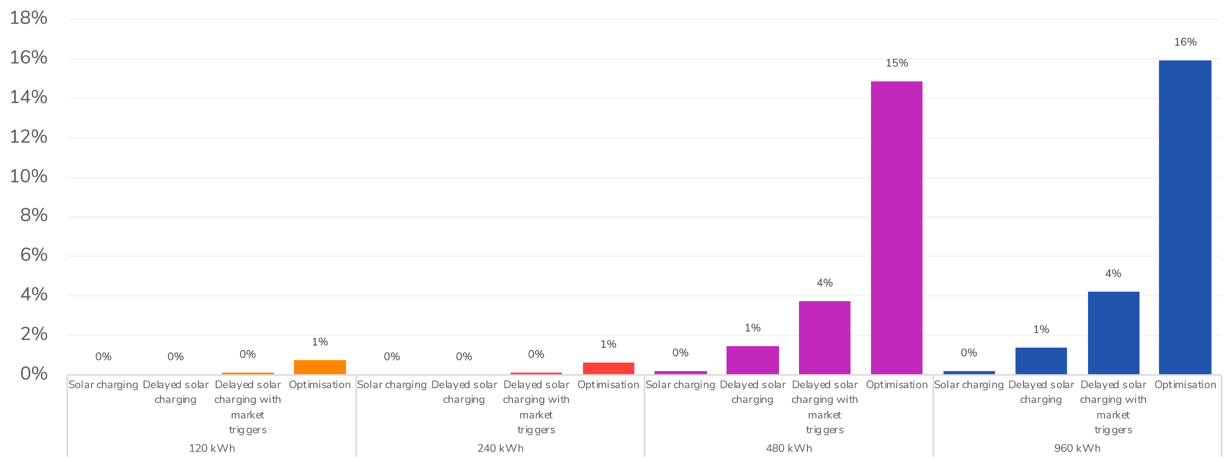


Figure 11 - Average percentage likelihood of providing 8 hours of back up to a 100kVA transformer by control profile for various battery sizes at current solar uptake

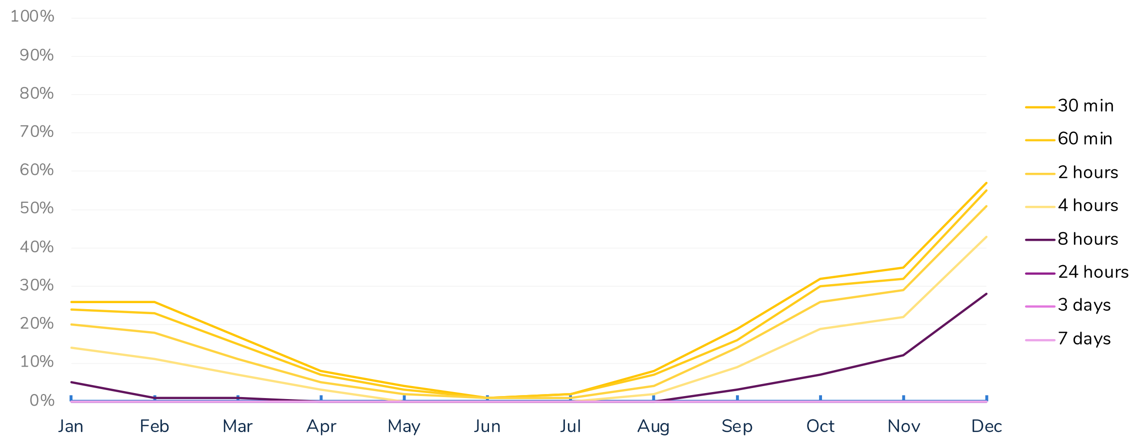
Box 5 further illustrates how the choice of control will greatly impact the ability of a battery to provide back-up power. This opportunity works particularly well due to the high solar uptake and the lack of any commercial loads.

Box 5 - Case study of transformer with neighbourhood battery providing back up power for two different control types

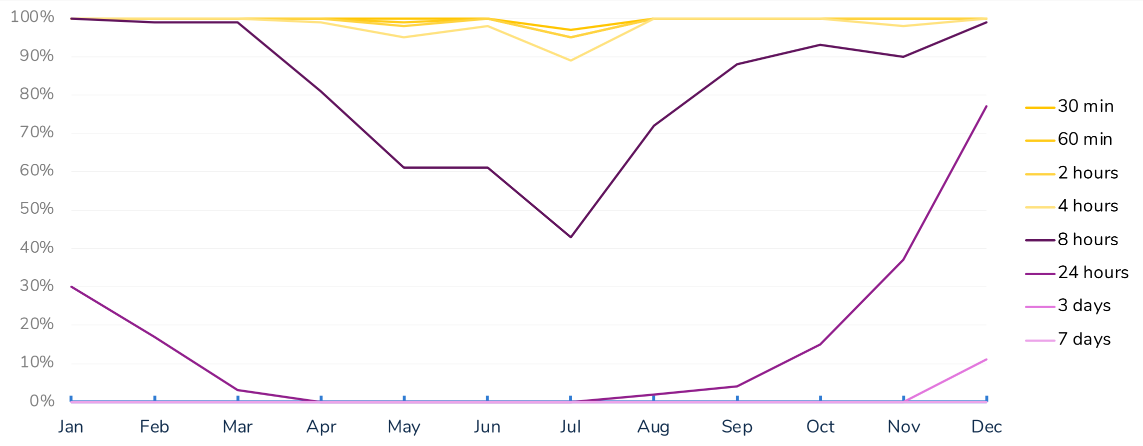
Neighbourhood Battery: Ballan	
Powercor Transformer ID	20387758-BAN006
Transformer size	25 kVA
Residential customers	10
Commercial customers	nil
Solar connections	5
Battery size	36 kW / 120 kWh

Below shows the percentage likelihood for a 120 kWh / 36 kW battery to provide back-up power for X minutes / hours / days for any interval in a month. Control profile 1 has a less than 5% average chance of delivering 8 hours of backup at any random interval, versus control profile 2 that has an average 82% chance.

Control profile 1: Delayed solar charging (Best for soft network capacity and energy independence where the battery tends to cycle daily and be fully discharged.)



Control profile 2: Optimisation (Best for financial return and grid resilience (apparently!) where the battery tends to cycle infrequently and be fully charged.)



7 Are neighbourhood batteries a solution for the future?

Short answer: Neighbourhood batteries benefits increase in line with solar uptake, but they are not an adequate or viable solution to the issues communities are expected to face in the future.

Given that a major motivation for communities is moving towards a zero net emissions local energy system, we naturally wanted to assess the solar carrying capacity of the transformers as part of this analysis, and whether neighbourhood batteries located at transformers will have a role to play in enabling this additional solar to come online.

In this section we:

- Simulate a 'future baseline' to understand how the underlying issues identified by communities are expected to change under future solar uptake scenarios.
- See whether neighbourhood batteries are a solution to the future identified issues.

7.1 Defining current and future solar uptake

Table 4 below shows that the average solar uptake across the transformers considered was approximately 16% but as high as 20% in Pomonal.

Table 4 – Estimation of total solar currently installed (existing), total solar potential across the villages and the current average solar uptake by village.

Village	Current Solar [kWp]	Solar Potential [kWp] 100% uptake	Average Solar Uptake today [%]
Ballan	1,508	9,524	16%
Clunes	643	4,303	15%
Pomonal	95	475	20%
Lyonville	113	614	18%
Glenlyon	108	660	16%
Wheatsheaf	132	739	18%
All towns	2,599	16,315	16%

Box 6- How we defined 'solar uptake'

The typically quoted 'solar uptake' figures used by the Australian PV Institute count the total dwellings with solar as a percentage of all dwellings.

We have defined solar uptake as a percentage of total solar potential, where the total solar potential is calculated as the sum of:

- Existing solar has been estimated based on the average system sizes by postcode as per APVI data multiplied by connection data as provided by Powercor; and
- The total potential solar that can be installed on homes and business assuming one system per connection and where the average solar size for each home is 6.6 kWp DC / 5.0 kVA AC and business is 19.8 kWp DC / 15 kVA AC
- There is no assessment of rooftop potential associated with our figures

7.2 Can batteries increase solar hosting capacity in the future?

7.2.1 Solar hosting capacity baseline (no batteries)

Baseline assessment: Most transformers will hit solar hosting capacity limits as solar uptake increases.

Before considering the impact of batteries, let's establish a 'future baseline' by assessing the solar hosting capacity of transformers in different future solar uptake scenarios, and compare it to today (without batteries). This analysis is charted in Figure 12 below.

Figure 12 clearly shows that the current capacity of local transformers will stop progress towards the stated community goals of high solar deployment, high energy independence, and equal access to solar PV for later adopters, unless something can be done about it.

As solar uptake increases towards 100%, so too does the percentage of transformers at or near their rated capacity. Lyonville and Pomonal are particularly pronounced due to their fleet of transformers generally being relatively small with most transformer sizes at or below 50kVA.

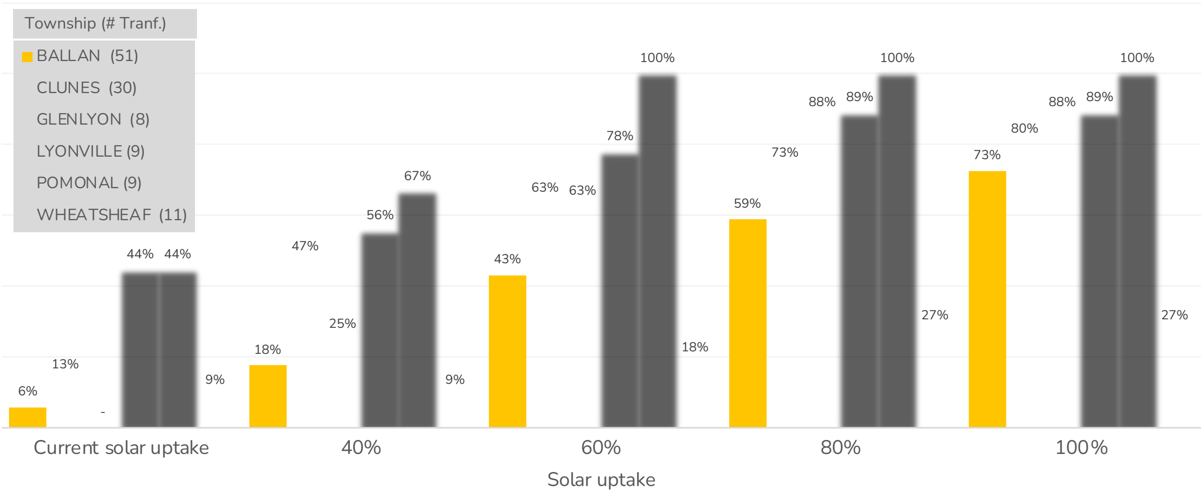


Figure 12 – Percentage of transformers at or near their rated solar carrying capacity[8]

7.2.2 Can batteries increase solar hosting capacity in the future?

Answer: Batteries can improve solar hosting capacity, mostly effectively at around 40% solar uptake.

Whilst the projections in Figure 12 present a terrible outcome for future solar PV installations in local areas, could it create the right conditions for neighbourhood batteries to be part of the solution?

To find out, we simulated a range of battery sizes at all sites, for all future solar uptake scenarios. The results are charted in Figure 13, below, which shows the number of transformers at maximum solar carrying capacity under a range of solar uptake scenarios and battery sizes.

As can be seen, as batteries are added and their size increases, there is a pronounced decline in the number of transformers at their maximum solar hosting capacity – particularly at a sweet spot of around 40% solar uptake.

Beyond this, the impact of neighbourhood batteries on increasing the solar hosting capacity drops off, as indicated by the flattening of the columns in the 60% and 80% solar uptake scenarios, as the battery size increases. This is largely because, at high levels of solar uptake, the batteries are too small for the volumes of solar energy being exported, resulting in batteries which spill and thereby no longer perform their function of soft network capacity provision.

This analysis shows that at future levels of solar uptake, particularly around 40% of all dwellings, neighbourhood batteries can provide benefits of soft network capacity and increased solar hosting capacity. However, the benefits only occur in some situations, and at a significant cost.

[8] See footnote 5 for our approach in determining transformers at or near their rated capacity.

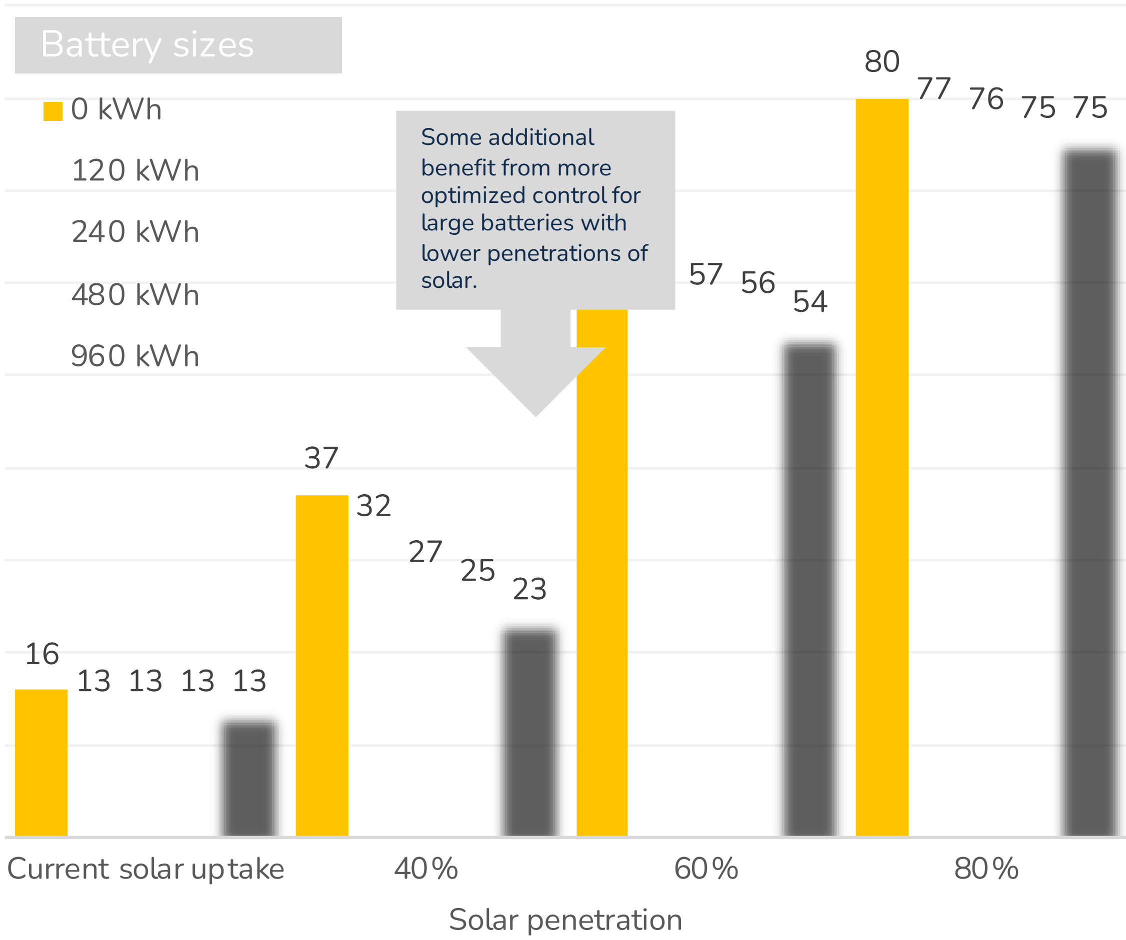


Figure 13- Number of transformers at maximum solar carrying capacity, by increasing solar uptake and battery sizes. (Delayed solar self-consumption control profile)

7.2.3 Can batteries improve energy independence in the future?

Answer: Batteries can substantially improve energy independence as solar uptake increases

Our analysis shows that a relatively small battery will dramatically improve the energy independence of a transformer as the solar uptake increases. There are generally diminishing benefits towards energy independence from larger batteries.

Figure 14 shows the energy independence of all transformers with various neighbourhood batteries of various sizes and Figure 15 shows the average energy independence of all transformers.

At 100% solar uptake, the smallest battery modelled (120 kWh) will increase the average energy independence of a transformer from 48% to 78%. However, Figure 14 shows that energy independence levels of up to 100% can be achieved in certain circumstances.

The case study in **Box 4** gives further illustration to the effectiveness of a neighbourhood battery to improve energy independence.

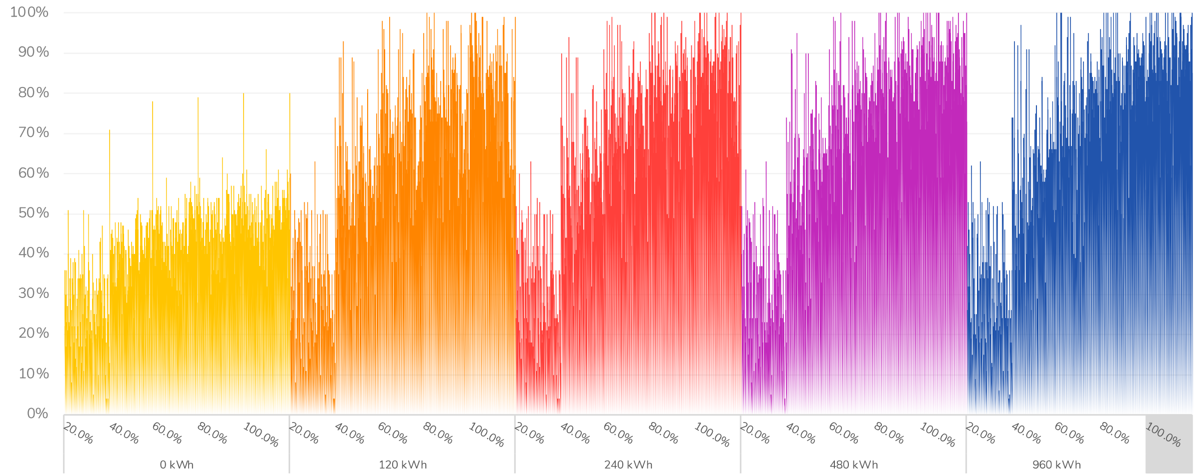


Figure 14 – Energy independence by transformer, solar uptake, and battery size for a neighbourhood battery with controlled for delayed solar charging (2910 simulations in total)

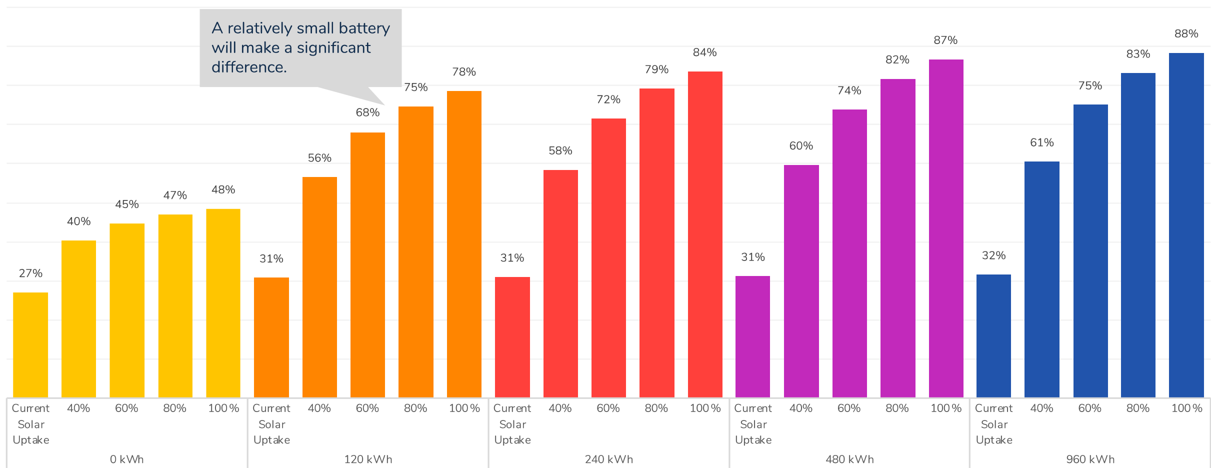


Figure 15 - Average energy independence for all transformers by solar uptake and battery size

7.2.4 Can neighbourhood batteries support grid resilience in the future?

Short answer: If solar uptake rises, yes

Our analysis shows that as solar uptake rises to 40%, a 120-kWh battery will have a 5% to 24% likelihood of meeting an 8-hour grid outage event[9]. This increases from 17% to 48% likelihood at 100% solar uptake. We have chosen 8 hours as the data showed 8 hour was the average length of an extended black out in 2021 and 8 hours of back up would cover over 80% of outages during these events (see section 5.3). Naturally the ability to meet back up power requirements is also highly contingent on the load of the transformer.

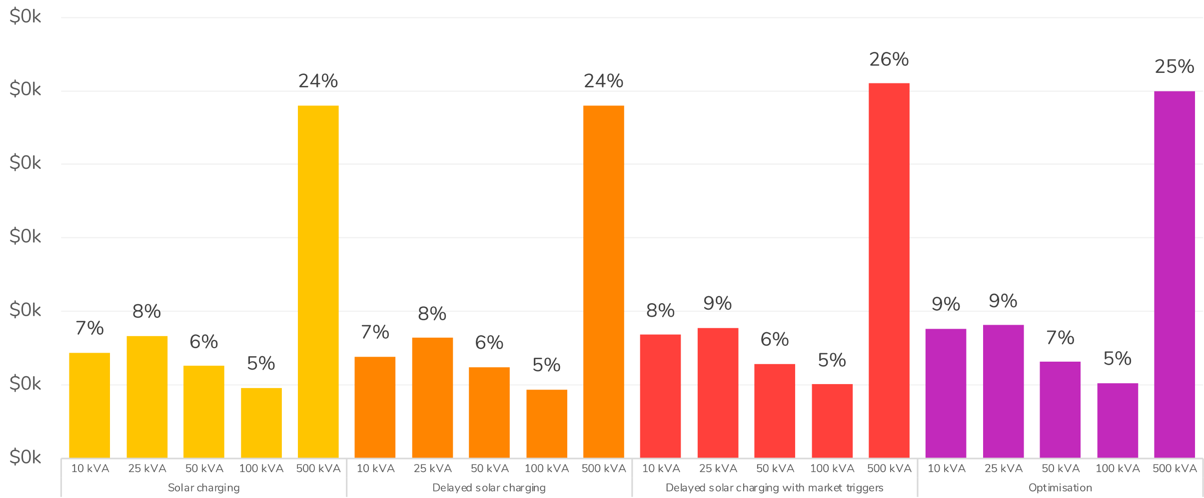


Figure 16 - Average percentage likelihood of a 120-kWh battery providing 8 hours of back up by transformer size for various control profiles at 40% solar uptake

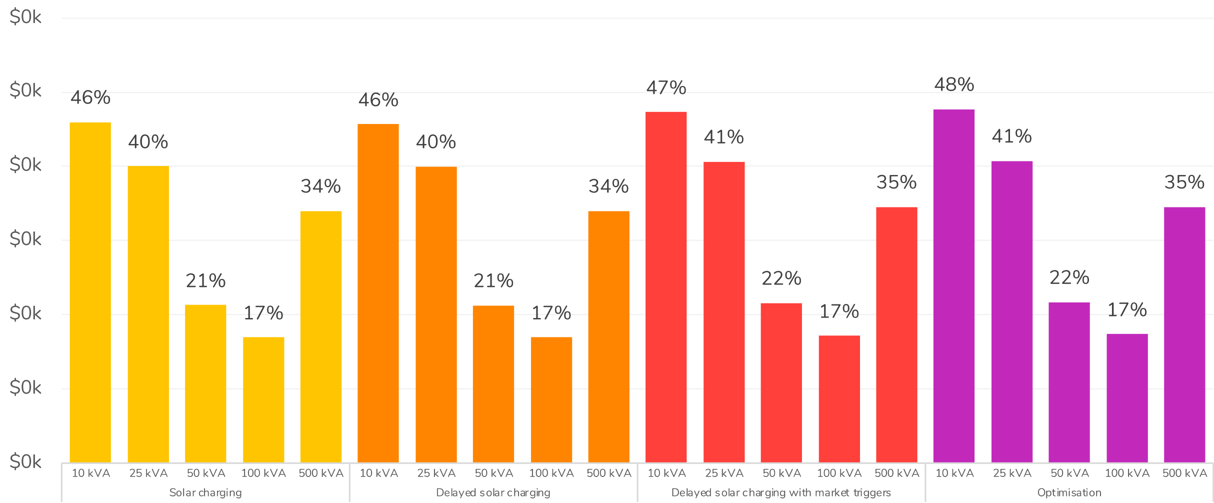


Figure 17 - Average percentage likelihood of a 120-kWh battery providing 8 hours of back up by transformer size for various control profiles at 100% solar uptake

[9] The 500kVA transformer sample here is being pulled up by an outlier. There are two 500 kVA transformers in the sample, one of them has just 8 homes and 1 business attached to it.

8 Are neighbourhood batteries financially viable?

Short answer: **No, not even close.**

We define project financial viability as the ability for a project proponent to receive a positive net present value over the 15-year project life, via direct value capture. This approach excludes indirect benefits of neighbourhood batteries (covered in section 9).

We assessed all projects for costs and revenues which can be directly captured by the project proponent (be it a community group or project developer). Depending on the control profile assessed (see 10.1 for information on control profiles), the project may derive earnings from the following activities:

1. Network tariff arbitrage
2. Wholesale tariff arbitrage
3. FCAS revenues

Out of the 11,640 simulations considered, Orkestra found no projects that were able to financially breakeven and, in most cases, did not earn enough to even cover its operating costs.

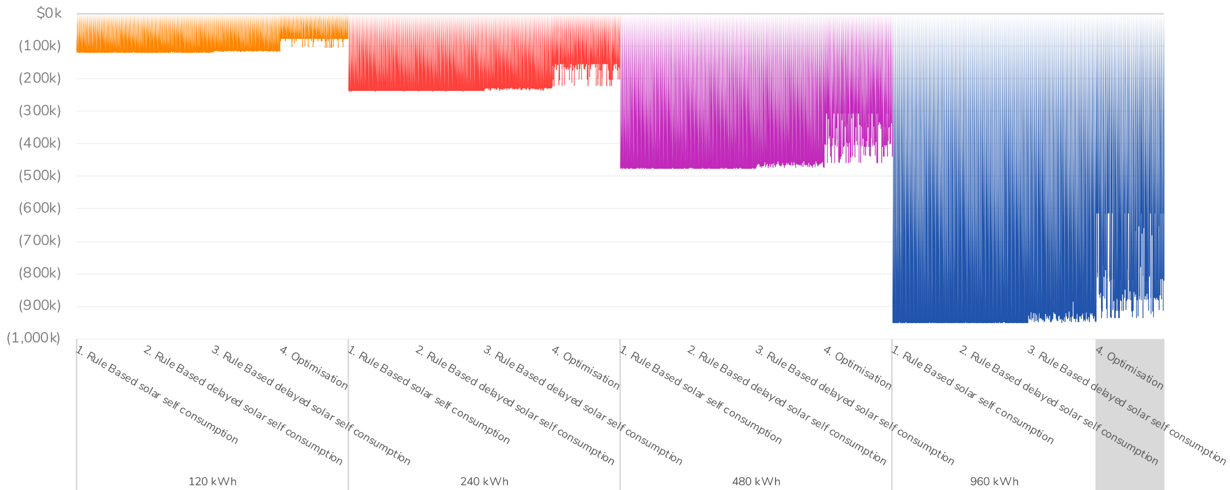


Figure 18 - NPV by transformer battery size and control profile for current solar uptake (2910 simulations in total)

Only batteries leveraging the optimisation control profile have come close to covering its costs.

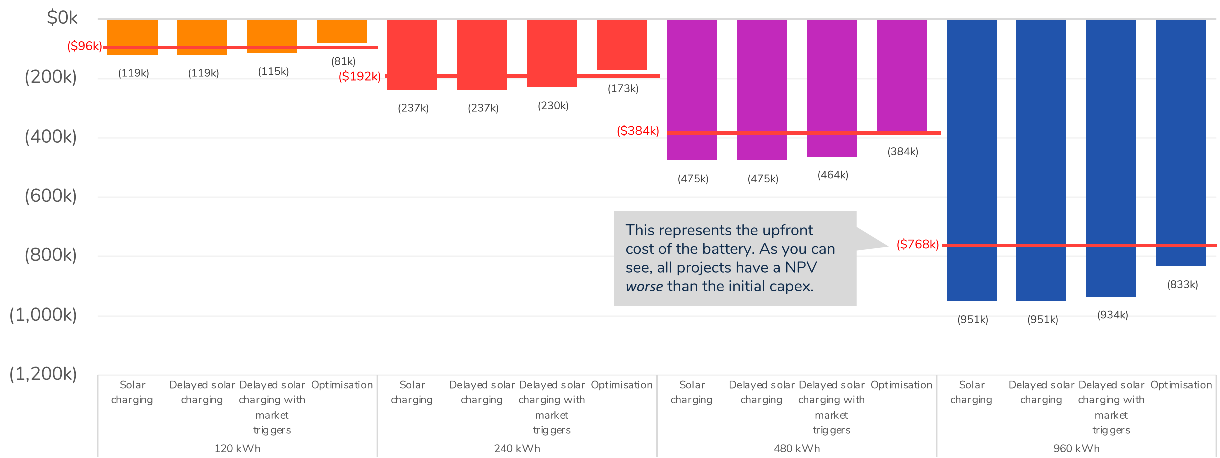


Figure 19 - Average battery NPV by control profile for various battery sizes for current solar uptake

Increasing the solar uptake has no effect as shown in Figure .

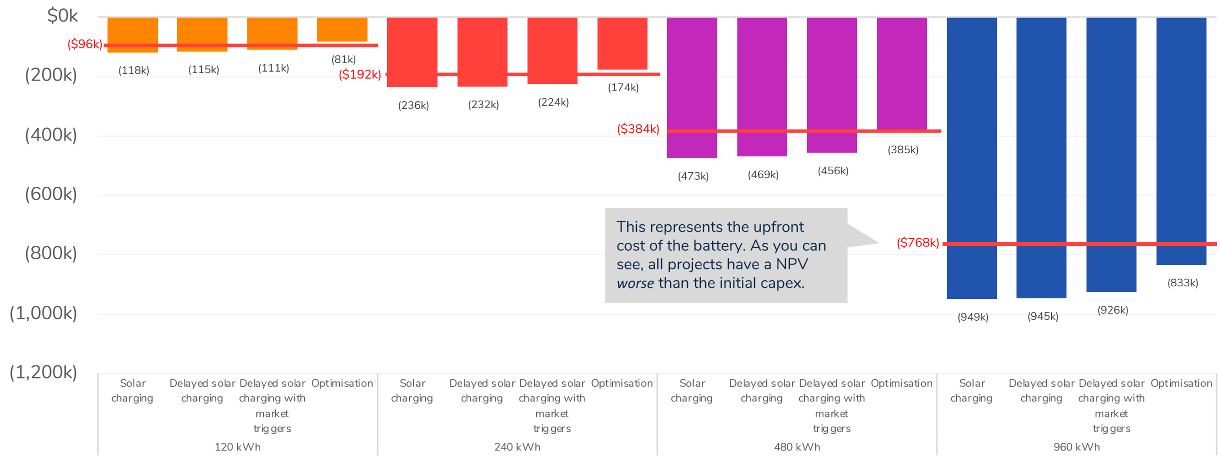


Figure 20 - Average battery NPV by control profile for various battery sizes at 100% solar uptake

The optimisation algorithm is the clear leader in terms of its ability to generate value, however, still fell well short of breaking even.

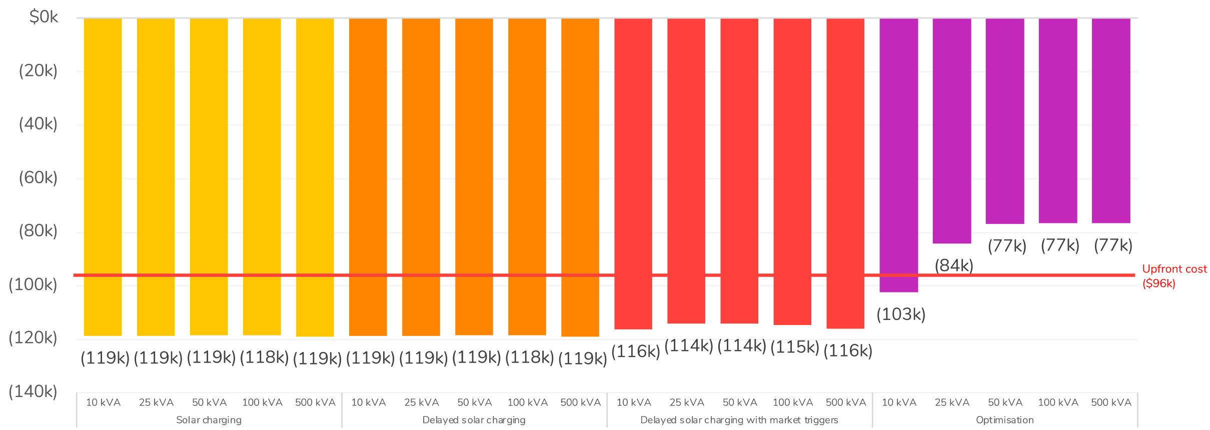


Figure 21 - Average battery NPV by transformer sizes for various control profiles at current solar uptake

Narrowing in on battery projects utilising the Optimisation battery control algorithm, we see that the biggest impact on NPV is transformer size. This is due to the battery targeting wholesale market arbitrage and contingency FCAS. These services favour batteries with no power constraints. A large battery - such as the 960 kWh / 288 kW battery considered in this analysis – will be unable to get its power into the grid if constrained behind a transformer with a small power rating.

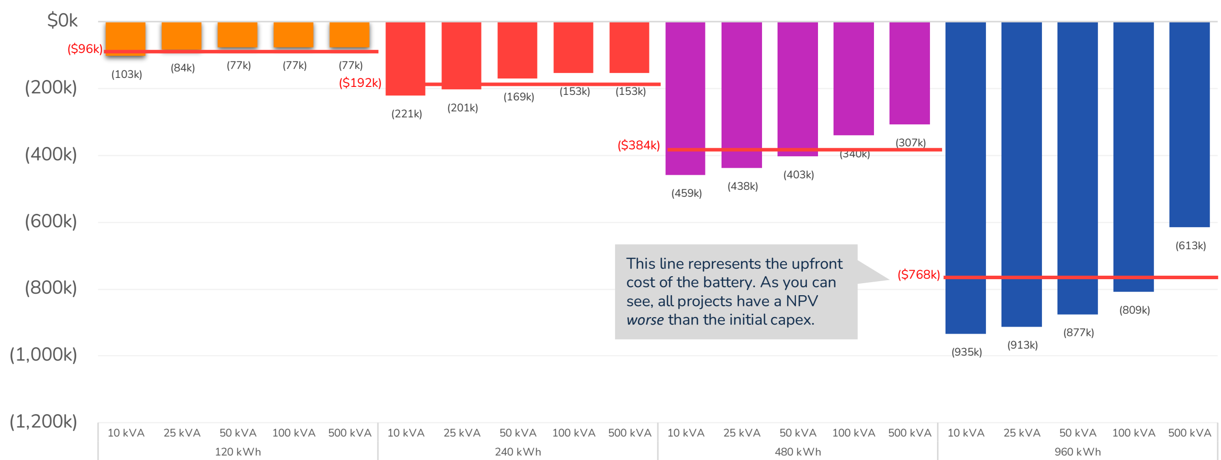


Figure 22 - Average NPV by transformer sizes and battery sizes at current solar uptake

The case study below provides the battery with highest NPV.

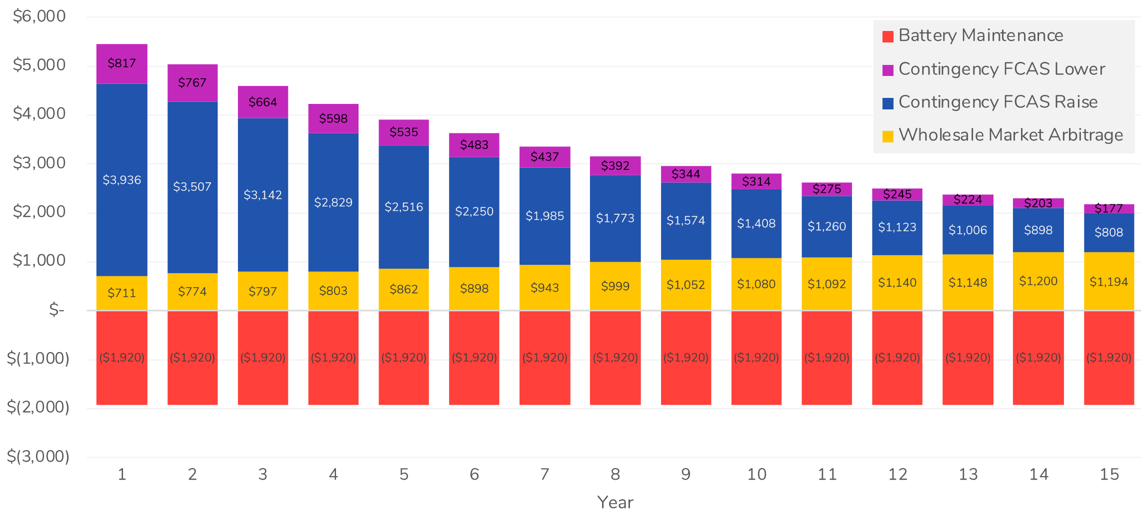
Box 7 - Case study of transformer with the highest NPV out of all opportunities considered

Below are details of the transformer with the highest NPV of the 11,640 scenarios considered. Even considering it is the highest NPV, the battery falls well short of breaking even. Interestingly, under this scenario soft network capacity lifts by 30%. However, there is no uplift in energy independence or back-up power potential.

Neighbourhood Battery:	**Clunes**					
Powercor Transformer ID	156944641-BAN006					
Transformer size	100 kVA					
Residential customers	33					
Commercial customers	5					
Resi. solar connections	14					
Comm. solar connections	Nil					
Technical specifications						
Battery size	36 kW / 120 kWh					
Control Profile	Optimisation					
Value stack description	Wholesale market arbitrage and contingency FCAS					
Financial summary						
15-year NPV Discount rate of 3%	($77k)					
Initial CAPEX	$96k					
Socials/environment benefits						
Solar connections enabled	Nil (Not at capacity)					
Est. soft network capacity	Before:	100kVA	After:	130kVA	**Uplift:**	**30kVA**
Est. solar hosting capacity	Before:	132kWp	After:	172kWp	**Uplift:**	**40kWp**
Est. energy independence at current solar uptake (36.4%)	Before:	31%	After:	31%	**Uplift**:	**0%**
Average percentage likelihood the battery can provide 8 hours of back up for any interval	**0%**					

Box 7- Case study of transformer with the highest NPV out of all opportunities considered (continued)

The charts below show the undiscounted nominal revenue and cost breakdown. The charts show the heavy weighting and dependence on contingency FCAS revenue with more than 70% of the value stack coming from this value stream.



8.1 Are there any financial upsides not considered in the analysis?

Short answer: Yes, there is some potential financial upside for the projects considered but don't get your hopes up.

Potential upsides include:

- Increasing volatility and rising prices in the wholesale market are likely to create a short-to-medium-term upside. However, the value of contingency FCAS is likely to degrade faster than we model.
- There are other potential value streams that relate to the energy market, providing grid services to Powercor and a shared-battery-as-a-service model, but in Orkestra's view, these are all extremely unclear as to whether they will be available to a neighbourhood battery and how a neighbourhood battery will commercialise them.
- Selection of a shorter duration battery.

8.1.1 Increasing volatility and/or high energy market prices

We have selected 2021 as our historical reference year for both the wholesale market and contingency FCAS markets to model the feasibility of neighbourhood batteries at the 118 transformer locations. For contingency FCAS we have applied an escalator of -10% to that market. Short of buying market forecasts, this approach is reasonable to provide a first pass analysis.

As shown in Figure 23 below, compared to previous years 2021 is a relatively high value year for batteries, but certainly not the highest value.

Orkestra's view of the wholesale energy market is that we are likely to be a long way from the top. This calendar year and the energy market chaos that ensued around May has only strengthened this view. As more renewables enter the system, we can expect the market to get more volatile. This however will be tempered by utility-scale battery projects entering the system as developers of these projects are increasingly incentivised to enter the market. As the adage goes in the energy market – *the solution to high prices is more high prices* - so similar to past experiences, the market value will likely be cyclical.

Orkestra's view of the contingency FCAS market is that it's likely to deflate faster than -10% in the near term and flatten out. This is due to it being a relatively shallow market. AER only needs to contract around 1000 MW in each National Energy Market region (i.e., NSW incl ACT, VIC, QLD, SA and TAS). Given the significant pipeline of utility-scale battery projects, any battery opportunity that relies solely on FCAS is likely to be a highly risky venture.

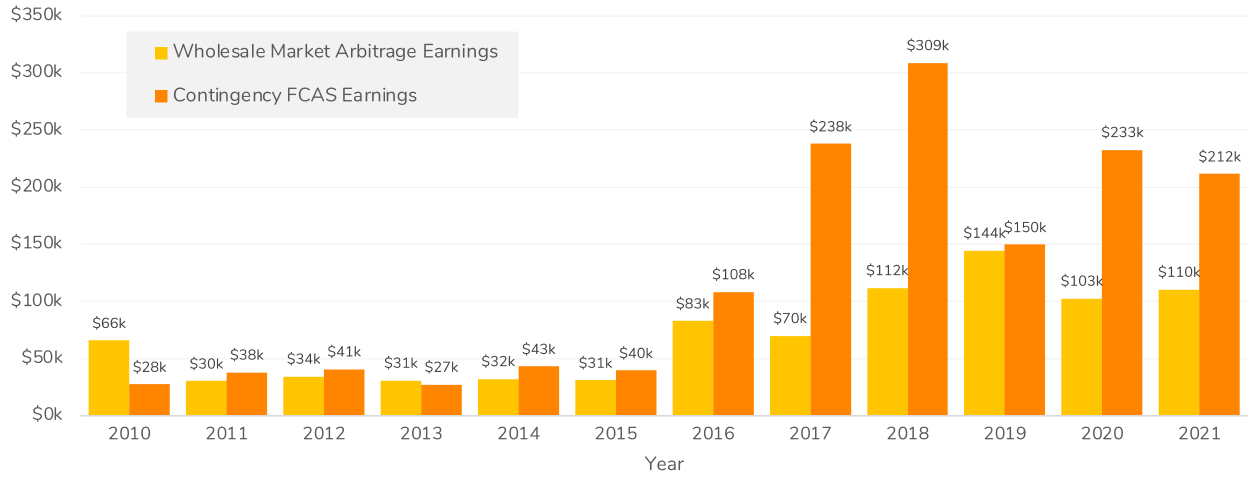


Figure 23 - Hypothetical annual earnings from 1MW/MWh battery – Wholesale Market Arbitrage and Contingency FCAS

8.1.2 Additional value streams

There are some potential value streams that may be available to neighbourhood batteries in the future that are not considered in our modelling:

- The AEMC has recommended a fast frequency market with sub-2 second response time to commence in October 2023. This will strongly favour batteries, and particularly those that are grid connected, but will likely increase the technical requirements of a battery. It is currently unknown whether the Relectrify batteries will conform to the requirements as they are not yet released.
- There are also plans for an inertia market and a capacity market however the details of these markets are unclear as well as whether neighbourhood batteries will be able to participate in them.
- There may be opportunities to provide grid services to Powercor in the future. We have attempted to value these benefits in the next chapter.
- There may be opportunities to provide a shared-battery-as-a-service model with the batteries but as discussed in Appendix C, the commercial and regulatory headwinds on this being widely available are very strong.

8.1.3 Shorter duration battery

While not considered in this analysis a shorter during battery will reduce the upfront costs while maintaining revenues in situations where the Optimisation control profile is used, and the battery is targeting wholesale market arbitrage and contingency FCAS. The preferred battery selected by CVGA was a 3.3-hour Relectrify battery. If a 1-hour battery were selected, the opportunity is more likely to financially breakeven.

However, any reduction of the duration of the battery will be at the expense of providing reliable back-up power. As we've maintained throughout this report, it's critical that neighbourhood battery proponents are clear about their drivers.

9 What is the total economic value of a neighbourhood battery?

In Chapter 8 we established that, of the 118 transformers assessed, not a single project option yielded a positive return on investment from direct revenue sources to the project developer.

But what if we add in the indirect benefits which flow to other stakeholders such as the network or the community? In this chapter, we attempt to quantify the indirect benefits of a community battery, relating them back to dollar terms. These savings cannot be monetised, or if they are monetary in nature, they cannot easily be monetised by the project developer.

In this section, we attempt to quantify the following indirect value streams:

- Value of soft network capacity to the network
- Value of soft network capacity to end customers (by enabling new solar capacity)
- Value of energy independence to communities
- Value of improved grid reliability

9.1 What is the value of soft network capacity to the Victorian electricity network?

There is value to the Victorian electricity network by avoided network upgrades. The counterfactual case for installing a neighbourhood battery is upgrading a transformer to the next size. While likely site-specific, we have attempted to tie the value of soft network capacity to the marginal cost of replacing a transformer up to the next size up.

Table 5 - Budgetary cost estimates for upgrading a transformer and the marginal value of soft network capacity by various transformer upgrades

Transformer upgrade	Total cost of upgrade	Soft network capacity value[10]
10 kVA -> 25 kVA	$15,000	$1000 / kVA
25 kVA -> 50 kVA	$20,000	$800 / kVA
50 kVA -> 100 kVA	$25,000	$500 / kVA
100 kVA -> 200 kVA	$30,000	$300 / kVA

[10] Marginal soft network capacity value is calculated as the total cost of upgrade divided by the difference between the upgraded transformer size and the previous size. E.g., Marginal soft network capacity value is $15,000 / (25 – 10) = $1000 per kVA.

200 kVA -> 500 kVA	$75,000	$250 / kVA
500 kVA -> 750 kVA[11]	$130,000	$520 / kVA

This value may be captured in the future through some type of services agreement with Powercor. To be clear, it is unlikely that Powercor would pass on all the value. Furthermore, we have applied this value against the upfront capital cost of a neighbourhood battery. In reality, this value will likely be paid over the life of the asset reflecting measured capacity savings the neighbourhood battery achieved.

9.2 What is the value of soft network capacity to end customers?

We have put a value of $965 per kWp of installed solar enabled by a community battery. This value relates to the 15-year net present value (NPV) of the savings that an end customer would obtain from installing solar that otherwise would not have been installed.

Our assumptions to this metric are in the table below. We have also assumed, very favourably to the projects, that the value of the solar is unlocked immediately (i.e., that the new solar in the community is commissioned at the same time as the battery.)

Table 6 -Input assumptions for the value of soft network capacity to end customers

Item	Assumption
Discount rate	3%
Solar CAPEX after incentives	$1000 /kWp
Solar system size	6.6 kW
Generation	1380 kWh / kWp p.a.
Panel degradation	0.5%
Average solar self-consumption	25%
Flat rate tariff cost	30 c/kWh (escalated at 2.5c/kWh)
Feed-in tariff	8 c/kWh (escalated at -7.5%)

[11] The largest pole-mounted transformer is 500 kVA. Increasing to 750 kVA will involve moving to a ground-mounted transformer that comes with it a new set of challenges relating to available land and aesthetics.

9.3 What is the value of energy independence to communities?

We have put a value of 3c/kWh on the energy locally produced and consumed at each transformer that is enabled by the battery. This is an estimation of potential willingness to pay. Fair to say, this is likely to be an optimistic valuation when most customers will likely expect the community battery to generate savings rather than add costs.

A benchmark for this cost would be the marginal cost of Green Power, which is currently in the order of 4.5 c/kWh but only about 2% of energy customers purchase Green Power.

To monetise this value, you would need to deploy the shared-battery-as-a-service business model. As discussed in Appendix C, there are significant commercial and regulatory challenges to this.

9.4 What is the value of improved grid reliability?

We used values for improved grid reliability that are published numbers by the Australian Energy Regulator (AER) for Value of Customer Reliability (VCR). These are listed in the table below.

VCR is applied to the unmet load of a transformer and factored by the percentage change of the battery providing 8 hours of backup for any random outage during the entire year. The unmet load is calculated as the total estimated baseline load multiplied by the number of hours that could be met by 8 hours of back up.

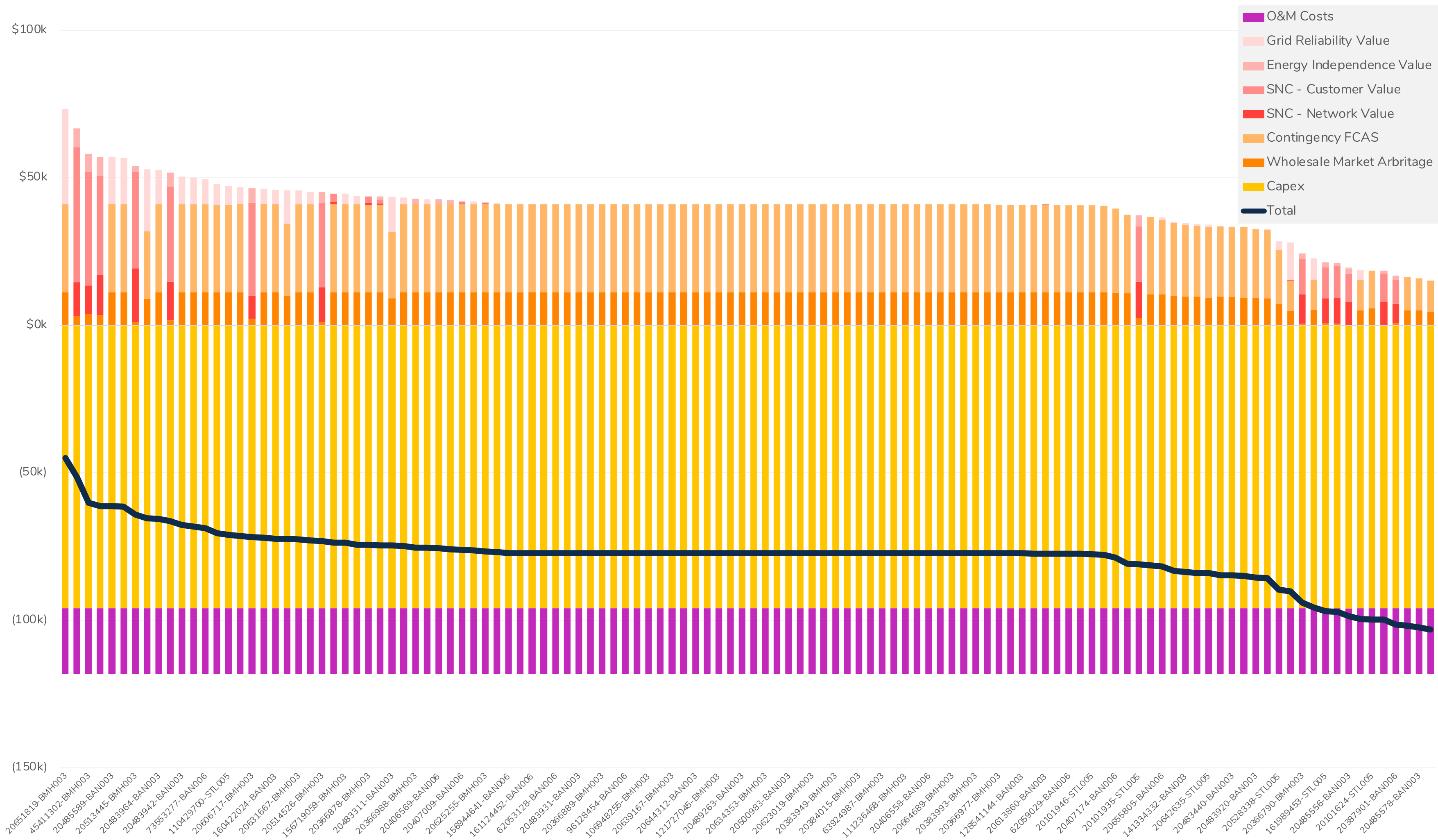
Table 7 – Value of Customer Reliability Assumptions

Sector	VCR
Residential (Climate Zone 6 – Regional)	$22.58 /kWh of unmet load
Commercial[12]	$46.18 /kWh of unmet load

9.5 What are the total indirect benefits of neighbourhood batteries?

Summing up the direct and indirect benefits of a neighbourhood battery to generate a "adjusted NPV", Figure 24 shows the total of the highest adjusted NPV for every transformer.

[12] Technically we need to split out agriculture and industrial customers but as most business sites in our data where classed as commercial, so we used this figure.



O&M Costs
Grid Reliability Value
Energy Independence Value
SNC - Customer Value
SNC - Network Value
Contingency FCAS
Wholesale Market Arbitrage
Capex
Total
$100k
$50k
$0k
(50k)
(100k)
(150k)
20651819-BMH003
45411302-BMH003
20485589-BAN003
20513445-BMH003
20483964-BAN003
20483942-BAN003
73553277-BAN006
110429700-STL005
20606717-BMH003
160422024-BAN003
20631667-BMH003
20514526-BMH003
156719059-BMH003
20366878-BMH003
20483311-BAN003
20366988-BMH003
20406569-BAN006
20407009-BAN006
20625255-BMH003
156944641-BAN006
161124452-BAN006
62053128-BAN006
20483931-BAN003
20366889-BMH003
96128454-BAN006
106948255-BMH003
20639167-BMH003
20644312-BAN003
121727045-BMH003
20489263-BAN003
20634353-BMH003
20500983-BAN003
20623019-BMH003
20383949-BMH003
20384015-BMH003
63924987-BMH003
111236468-BMH003
20406558-BAN006
20664689-BMH003
20383993-BMH003
20366977-BMH003
128541144-BAN003
20613860-BAN003
62059029-BAN006
20101946-STL005
20407174-BAN006
20101935-STL005
20655805-BAN006
141334332-BAN003
20642635-STL005
20483440-BAN003
20483920-BAN003
20528338-STL005
20366790-BMH003
161989453-STL005
20485556-BAN003
20101624-STL005
20387901-BAN006
20485578-BAN003

Figure 24 – “Best project” by transformer ranked in terms of 15-year adjusted NPV – the NPV of direct value and indirect benefits including grid reliability value, energy independence value, and benefits from soft network capacity (SNC) to the network and end customers.

Box 8 - Case study of 500kVA transformer in Ballan with a 120-kWh battery participating in the energy markets while providing improved grid reliability

Neighbourhood Battery: Ballan				
Powercor Transformer ID	20651819-BMH003			
Transformer Size	500 kVA			
Residential customers	*Total*	8	*With solar*	2
Commercial customers	*Total*	1	*With solar*	nil
Solar connected [kWp]	*Current*	10.4 kWp	*New*	18.6 kWp
Solar uptake [%]	Current	14.3 %	New	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			

The waterfall chart below shows the build-up of value. In this case, there is no value from soft network capacity (SNC) or energy independence.

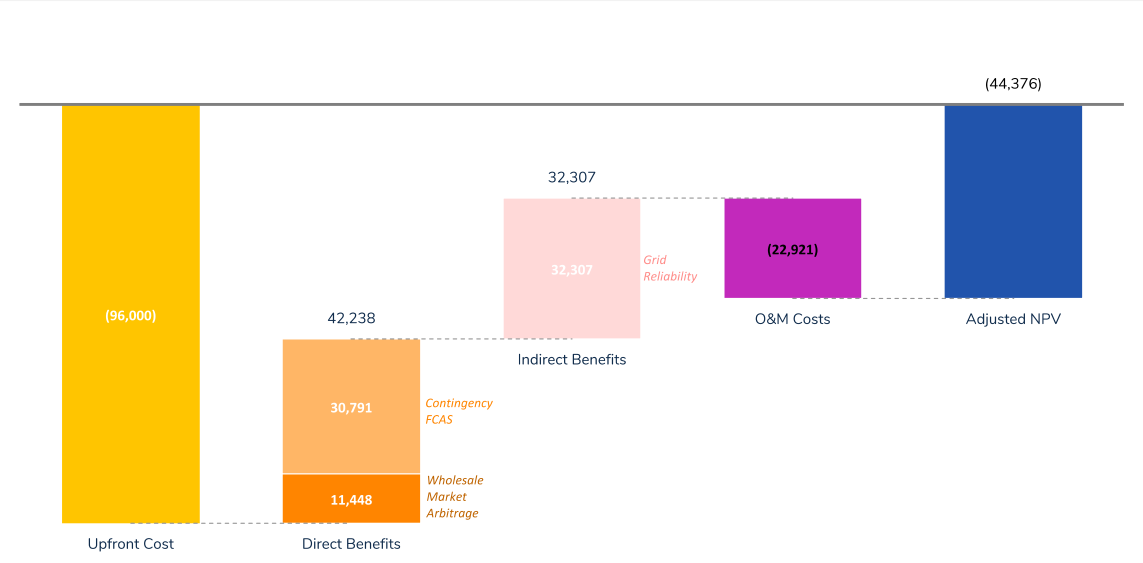


Figure 25 – Waterfall chart of indirect value contributing to the adjusted NPV for Ballan Transformer 20651819-BMH003.

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Box 9 - Case study of 100kVA transformer in Ballan with a 120-kWh battery providing soft network capacity and improved energy independence

Neighbourhood Battery: Ballan				
Powercor Transformer ID	20647865-BMH003			
Transformer Size	100 kVA			
Residential customers	*Total*	29	*With solar*	14
Commercial customers	*Total*	1	*With solar*	Nil
Solar connected [kWp]	*Current*	72.8 kWp	*New*	11.7 kWp
Solar uptake [%]	Current	34.5%	New	40%
Solar hosting capacity available?	Yes, just.			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	2. Delayed Solar Charging			
Value stack description	Soft network capacity and energy independence			

The waterfall chart below shows the build-up of value. In this case, there is no value from Grid Reliability.

Figure 26 – Waterfall chart of indirect value contributing to the adjusted NPV for Ballan Transformer 20647865-BMH003

10 What are the “best projects” for CVGA?

In this section we provide:

1. A discussion on the trade-offs which must be considered when attempting to select the ‘best’ projects.
2. Recommendations for the most suitable project in each village.
3. Recommendations on the most suitable battery control profile.
4. A general summary of the steps to be taken to progress the project to being investment ready.
5. An overview of the risks and opportunities that these recommended projects are likely to encounter.

10.1 How to select the ‘best project’: can neighbourhood batteries deliver on all drivers?

Short answer: No – none of the projects were able to deliver on all the drivers.

In this report we have been working towards meeting the following drivers:

- Unlocking more solar on low voltage distribution networks that are increasingly constrained
- Increasing the energy independence and self-sufficiency of communities in the communities represented by CVGA
- Improving local reliability and energy resilience
- Unlocking new financial value for individuals and communities to help manage energy affordability

Ultimately it will be a trade-off between drivers and their corresponding value streams. (In Chapter 9, we attempt to balance all the objectives by putting an economic value to soft network capacity, energy independence and grid reliability to find the most economic project.) The trade-off comes down (mostly) to the chosen battery control algorithm.

In the table below we look at a comparison of various control profile options for a single site. Note that in this case, we were able to find a site where the utilisation of different control algorithms was able to generate the full range of indirect benefits in one case or another. Fair to say that this transformer is an outlier, and, in most cases, we were only able to find a transformer that delivered either soft network capacity and energy independence value OR grid reliability value.

Table 8 - Comparison of key metrics for the various control profiles on a 120kWh battery installed on transformer 20485589-BAN003 in Lyonville with a name plate rating of 50kVA with 10 residential customers, 6 already with solar at current solar uptake (43%).

Control profile	1. Solar charging	2. Delayed solar charging	3. Delayed solar charging with market triggers	4. Optimisation[13]
Upfront Cost	($96,000)	($96,000)	($96,000)	($96,000)
Wholesale Market Arb.	$663	$661	$3,215	$11,448
Contingency FCAS	Nil	Nil	$1,987	$30,788
O&M Costs	($22,921)	($22,921)	($22,921)	($22,921)
NPV (Subtotal)	($118,258)	($118,260)	($113,720)	($76,685)
SNC – Network Value	$8,137	$8,137	$1,948	Nil
SNC – Customer Value	$19,693	$19,693	$7,859	Nil
Energy Ind. Value	$3,002	$2,752	$2,808	Nil
Grid Reliability Value	Nil	Nil	Nil	$15,894
Adjusted NPV	($87,426)	($87,678)	($101,909)	($60,791)

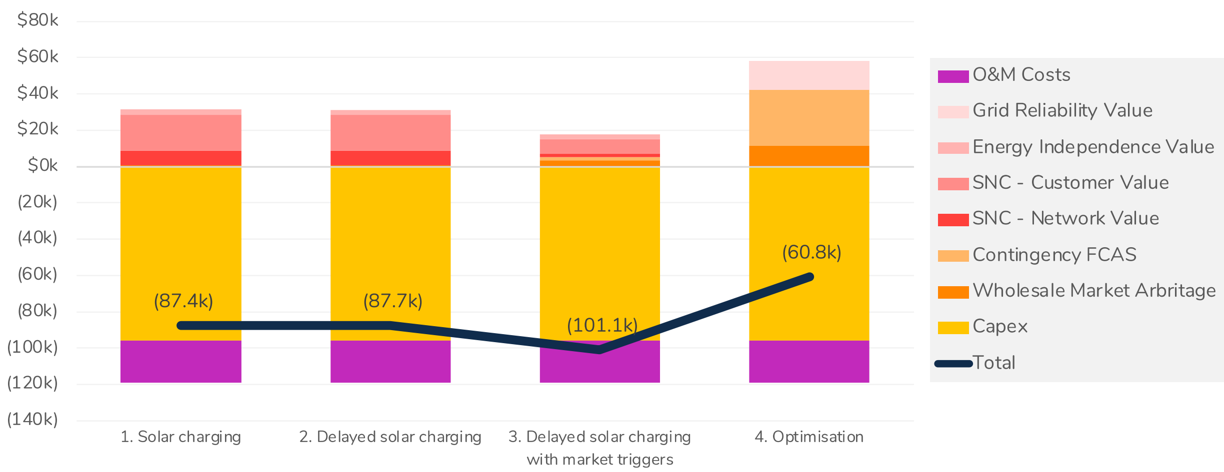

Figure 27 – Comparison of key metrics for the various control profiles outlined in Table 8

[13] For this case we used a solar uptake of 60% rather than the current solar uptake to demonstrate the point as not back up potential was determined for the current solar uptake case.

10.2 What are the “best projects” for neighbourhood batteries, and do they deliver a net economic benefit?

Short answer: No – none of the projects were able to deliver a net economic benefit.

The “best projects” for neighbourhood batteries among the 118 transformers considered have the following characteristics:

- A battery size of 120 kWh
- Are controlled using the Optimisation algorithm
- Create additional economic benefit came from improved grid reliability

To provide a recommendation to CVGA and their partners on which are the “best projects”, we have selected the battery projects with the highest adjusted NPV by village – i.e., will deliver the greatest economic benefit. As a reminder, the adjusted NPV is the 15-year net present value of both direct and indirect value. The battery projects with the highest NPV by village are listed in Table 9.

Table 9 – The “best products” by village – those with the highest adjusted NPV and economic benefit

Village	Transformer	Transformer Size	NPV	Adjusted NPV	Battery Size	Control Algorithm
Ballan	20651819-BMH003	500 kVA	$(76.7k)	$(44.4k)	120 kWh	Optimisation
Clunes	73553277-BAN006	50 kVA	$(76.7k)	$(68.2k)	120 kWh	Optimisation
Glenlyon	108027199-STL005	50 kVA	$(76.8k)	$(69.9k)	120 kWh	Optimisation
Lyonville	20485589-BAN003	50 kVA	$(76.7k)	$(60.8k)	120 kWh	Optimisation
Pomonal	41083650-BAN003	50 kVA	$(76.7k)	$(60.9k)	120 kWh	Optimisation
Wheatsheaf	20483964-BAN003	100 kVA	$(76.7k)	$(65.1k)	120 kWh	Optimisation

For each recommendation we have provided a technical overview of each battery, financial summaries and the social/environmental benefits of each project including an estimation of local procurement benefits[14].

[14] In the context of this report and as required by the Victorian State Government, ‘local’ means all suppliers producing Victorian, Australian or New Zealand goods or services or when they have added value to imported items, such providing a local employment outcome to an imported product.

10.2.1 Ballan

Neighbourhood Battery: Ballan				
Powercor Transformer ID	20651819-BMH003			
Transformer Size	500 kVA			
Residential customers	*Total*	8	*With solar*	2
Commercial customers	*Total*	1	*With solar*	nil
Solar connected [kWp]	*Current*	10.4 kWp	*New*	18.6 kWp
Solar uptake [%]	Current	14.3 %	New	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($76,700)			
15-year adjusted NPV NPV of direct and indirect value	($44,400)			
Indirect value	*Source*	Grid reliability	*Value*	$32,300
Initial CAPEX	$96,000			
15-year CAPEX & OPEX Discount rate of 3%	$ 118,900			
Year 1 Total Revenue	$ 3,540			
Year 1 Network savings	$ 2,706			
Year 1 Customer savings	Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				
Enabled solar connections	Nil (no capacity constraint)			
Est. soft capacity uplift [kVA]	Before: 500	After: 519	Uplift: 19	
Est. solar hosting uplift [kWp]	Before: 660	After: 685	Uplift: 25	
Est. energy ind. Uplift [%]	Before: 23%	After: 21%	Uplift: -2%	
Back-up power potential	50% likely to provide 8-hours of back-up			

Est. of local procurement	100%

10.2.2 Clunes

Neighbourhood Battery: Clunes				
Powercor Transformer ID	73553277-BAN006			
Transformer Size	50 kVA			
Residential customers	*Total* 10		*With solar*	3
Commercial customers	*Total* 1		*With solar*	nil
Solar connected [kWp]	*Current* 14.4 kWp		*New*	19.9 kWp
Solar uptake [%]	Current 16.8 %		New	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($76,700)			
15-year adjusted NPV NPV of direct and indirect value	($68,200)			
Indirect value	*Source* Grid reliability		*Value*	$8,465
Initial CAPEX	$96,000			
15-year CAPEX & OPEX Discount rate of 3%	($118,900)			
Year 1 Total Revenue	$ 3,538			
Year 1 Network savings	$ 709			
Year 1 Customer savings	$ Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				
Enabled solar connections	Nil (no capacity constraint)			
Est. soft capacity uplift [kVA]	Before: 50	After: 74	Uplift: 24	
Est. solar hosting uplift [kWp]	Before: 66	After: 98	Uplift: 32	
Est. energy ind. Uplift [%]	Before: 39%	After: 37	Uplift: -2%	

Back-up power potential	34% likely to provide 8-hours of back-up
Est. of local procurement	100%

10.2.3 Glenlyon

Neighbourhood Battery: Glenlyon				
Powercor Transformer ID	41083650-BAN003			
Transformer Size	50 kVA			
Residential customers	*Total*	10	*With solar*	3
Commercial customers	*Total*	1	*With solar*	nil
Solar connected [kWp]	*Current*	9.4 kWp	*New*	19.6 kWp
Solar uptake [%]	Current	12.9%	New	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($76,700)			
15-year adjusted NPV NPV of direct and indirect value	($60,900)			
Indirect value	*Source*	Grid reliability	*Value*	$15,800
Initial CAPEX	$96,000			
15-year CAPEX & OPEX Discount rate of 3%	($118,900)			
Year 1 Total Revenue	$ 3,542			
Year 1 Network savings	$ 1,323			
Year 1 Customer savings	$ Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				
Enabled solar connections	Nil (no capacity constraint)			
Est. soft capacity uplift [kVA]	Before: 50	After: 68	Uplift: 18	
Est. solar hosting uplift [kWp]	Before: 66	After: 90	Uplift: 24	

Est. energy ind. Uplift [%]	Before: 40% After: 37% Uplift: -3%
Back-up power potential	29% likely to provide 8-hours of back-up
Est. of local procurement	100%

10.2.4 Lyonville

Neighbourhood Battery: Lyonville				
Powercor Transformer ID	20485589-BAN003			
Transformer Size	50 kVA			
Residential customers	*Total*	10	*With solar*	6
Commercial customers	*Total*	Nil	*With solar*	Nil
Solar connected [kWp]	*Current*	28.2 kWp	*New*	11.4 kWp
Solar uptake [%]	Current	42.7 %	New	60%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($76,700)			
15-year adjusted NPV NPV of direct and indirect value	($60,800)			
Indirect value	*Source*	Grid reliability	*Value*	$15,900
Initial CAPEX	$96,000			
15-year CAPEX & OPEX Discount rate of 3%	$118,900			
Year 1 Total Revenue	$ 3,540			
Year 1 Network savings	$ 1,331			
Year 1 Customer savings	$ Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				
Enabled solar connections	Nil (no capacity constraint)			
Est. soft capacity uplift [kVA]	Before: 50	After: 73	Uplift: 23	

Est. solar hosting uplift [kWp]	Before:	66	After:	96	Uplift:	30
Est. energy ind. Uplift [%]	Before:	49%	After:	47%	Uplift:	-2%
Back-up power potential	17% likely to provide 8-hours of back-up					
Est. of local procurement	100%					

10.2.5 Pomonal

Neighbourhood Battery: Pomonal				
Powercor Transformer ID	108027199-STL005			
Transformer Size	50 kVA			
Residential customers	*Total*	4	*With solar*	2
Commercial customers	*Total*	4	*With solar*	nil
Solar connected [kWp]	*Current*	13.6 kWp	*New*	28.6
Solar uptake [%]	Current	12.9 %	New	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($76,700)			
15-year adjusted NPV NPV of direct and indirect value	($69,900)			
Indirect value	*Source*	Grid reliability	*Value*	$6,900
Initial CAPEX	$96,000			
15-year CAPEX & OPEX Discount rate of 3%	($118,900)			
Year 1 Total Revenue	$ 3,519			
Year 1 Network savings	$ 580			
Year 1 Customer savings	$ Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				
Enabled solar connections	Nil (no capacity constraint)			

Est. soft capacity uplift [kVA]	Before:	50	After:	79	Uplift:	29
Est. solar hosting uplift [kWp]	Before:	66	After:	105	Uplift:	38
Est. energy ind. Uplift [%]	Before:	43%	After:	41%	Uplift:	-2%
Back-up power potential	61% likely to provide 8-hours of back-up					
Est. of local procurement	100%					

10.2.6 Wheatsheaf

Neighbourhood Battery: Wheatsheaf				
Powercor Transformer ID	20483964-BAN003			
Transformer Size	100 kVA			
Residential customers	*Total*	6	*With solar*	2
Commercial customers	*Total*	Nil	*With solar*	Nil
Solar connected [kWp]	*Current*	9.4 kWp	*New*	6.4 kWp
Solar uptake [%]	*Current*	23.7 %	*New*	40%
Solar hosting capacity available?	Yes			
Technical specifications				
Battery size	120 kWh / 36 kW			
Value stack	Optimisation			
Value stack description	Wholesale market arbitrage, contingency FCAS participation and semi-reliable back-up power			
Financial summary				
15-year NPV Discount rate of 3%	($ 76,700)			
15-year adjusted NPV NPV of direct and indirect value	($ 65,100)			
Indirect value	*Source*	Grid reliability	*Value*	$ 11,600
Initial CAPEX	$ 96,000			
15-year CAPEX & OPEX Discount rate of 3%	$ 118,900			
Year 1 Total Revenue	$ 3,543			
Year 1 Network savings	$ 970			
Year 1 Customer savings	Nil			
Grant req. to breakeven	$ 76,700			
Socials/environment benefits				

Enabled solar connections	Nil (no capacity constraint)
Est. soft capacity uplift [kVA]	Before: 100 After: 111 [illegible]
Est. solar hosting uplift [kWp]	Before: 132 After: 14[illegible]
Est. energy ind. Uplift [%]	Before: 39% After: [illegible]
Back-up power potential	52% likely to provide 8-[illegible]
Est. of local procurement	100%

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Neighbourhood Battery Initiative
Final report

PART B: NEIGHBOURHOOD BATTERY HANDBOOK

Introduction to Part B: Neighbourhood Battery Handbook.

This section provides important background information for a proponent considering the development of any neighbourhood battery project. Whilst written to support the CVGA brief, we have intended to write a stand-alone section of the document which can be read by other community organisations in Australia.

In Part B we:

- Introduce the concept of neighbourhood batteries, including how to think about their benefits and costs.
- Outline the key practical considerations a neighbourhood battery project including the technical, commercial, and operational aspects.
- Discuss what defines a successful neighbourhood battery.
- Discuss potential cost-effective alternatives to neighbourhood batteries.

11 Introduction to neighbourhood batteries

In this section we provide:

- An introduction to the concept of neighbourhood battery
- An overview of the drivers of a neighbourhood battery
- A description of the services that a neighbourhood battery can provide, and
- Introduce the concept of a value stack.

11.1 What is a neighbourhood battery?

The Victorian Government defines neighbourhood batteries (also called community-scale or community batteries) as a type of energy storage model that can provide multiple benefits to consumers, communities, and the electricity system.[15]

The Government also specify neighbourhood batteries as:

- Having a capacity from 100kWh up to 5MWh and can service a neighbourhood of approximately 20-100 households.
- Offering similar functionality to utility-scale batteries.

[15] See FAQ of https://engage.vic.gov.au/victorian-neighbourhood-battery-initiative-consultation

- Being connected 'in front of the meter' to the electricity distribution network, rather than 'behind the meter' in a household or business premises. A neighbourhood scale battery would typically be located at street level close to where electricity is being both consumed by homes and generated from rooftop solar.

It is important to recognise that there is no agreed definition but an important distinction between a community-scale battery and a community-owned battery. Many community groups that have developed community-owned energy assets (including the funders of this report, Hepburn Wind, who developed the Hepburn Wind Farm Project) are now taking interest in community-scale batteries.

However, the community ownership of energy assets and the physical location of energy assets within a community need to be considered as two very different things. That said, they are commonly merged into the concept of a neighbourhood battery.

For the purposes of this report, we have adopted the Victorian Government's definition but have extended on it below.

11.2 What are the drivers for a neighbourhood battery

CVGA commissioned this report due to communities and councils across central and northwest Victoria expressing strong interest in neighbourhood batteries as a potential option to address multiple problems and opportunities in the region such as:

- Unlocking more solar installations on low voltage distribution networks that are increasingly constrained
- Accelerating the shift to zero net emissions electricity
- Unlocking new value streams for communities to help manage energy bills
- Improving local reliability and energy resilience
- Addressing equity issues for households who cannot afford solar and or batteries

This was further confirmed by Hepburn Energy which undertook a survey of 246 people on their expectations of the benefits of neighbourhood batteries. Well over half the respondents viewed "progressing Z-NET"[16], improving resilience, increasing local self-sufficiency, and carbon savings as "very important" benefits of neighbourhood batteries. (Comparatively only a third of respondent saw financial benefits as a "very important" benefit).

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[16] Z-NET stands for Zero Net Energy Town. It is a shared set of resources to support rural towns, villages, and regions throughout Australia to satisfy their own energy needs from renewable energy sources in a way which is competitive with its current system of energy (in terms of price, quality, reliability, security of supply and so on). More details can be found at: https://z-net.org.au/

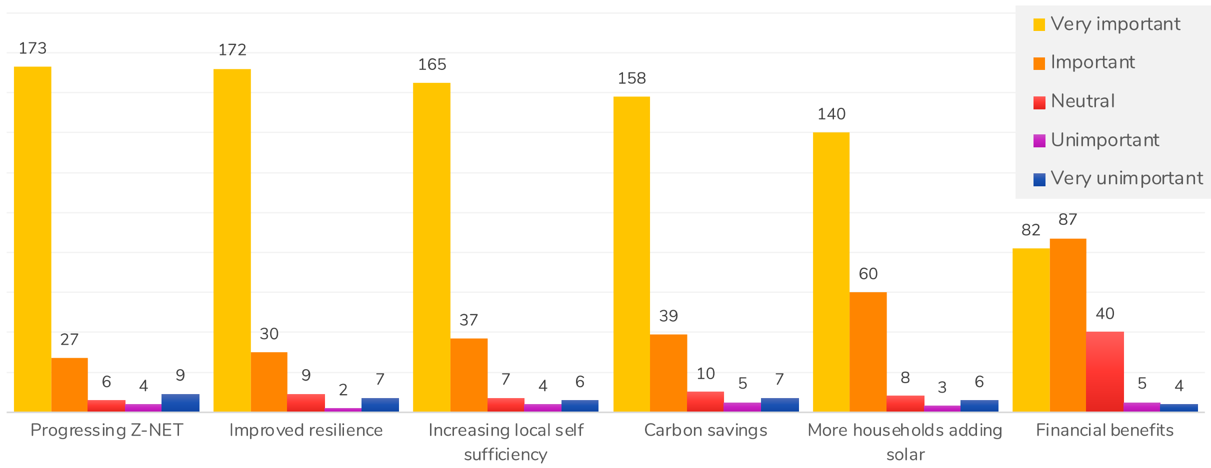

Figure 28 - Answers to the Question: “In regard to community batteries, how important are the following benefits to you?” in a recent Hepburn Energy survey results on neighbourhood batteries (N = 246).

Similarly, the NBI consultation commissioned by the Victorian State Government[17] determined that 80% of the 312 respondents to the consultation expected the benefits of a community battery to include carbon reductions, the ability to access storage without needing to buy a battery, and support for more solar on the grid.

Many people in the community see neighbourhood batteries as a pathway to a variety of environmental, social, and economic benefits. While we don’t question the enthusiasm for neighbourhood batteries, our detailed analysis in Part A shows that there is a wide gulf between the expectations on neighbourhood batteries and the challenge they face achieving commercial viability.

Significant trade-offs exist between the various requirements, especially when weighing up non-financial drivers versus financial ones. Communities seeking to deploy a neighbourhood battery will need to clearly determine their drivers and what is most important to their unique situation. For example, a battery that has a primary requirement to improve grid resilience and support during natural disasters will unlikely be able to perform many other services that create revenue for the battery but require it to be regularly discharging.

The drivers of a community for a neighbourhood battery will ultimately determine the services that a neighbourhood battery must provide.

[17] See https://engage.vic.gov.au/victorian-neighbourhood-battery-initiative-consultation

11.3 What services can a neighbourhood battery provide?

Batteries are so versatile in their use cases that they are often referred to as the 'Swiss army knife' of energy technology. This is exemplified by the now famous RMI Battery Value Wheel (see Figure 29 below). In all cases, as a simple rule of thumb, the service of a battery is to charge with electricity at times that it is "low value" and discharge during times that electricity is (comparatively) "high value".

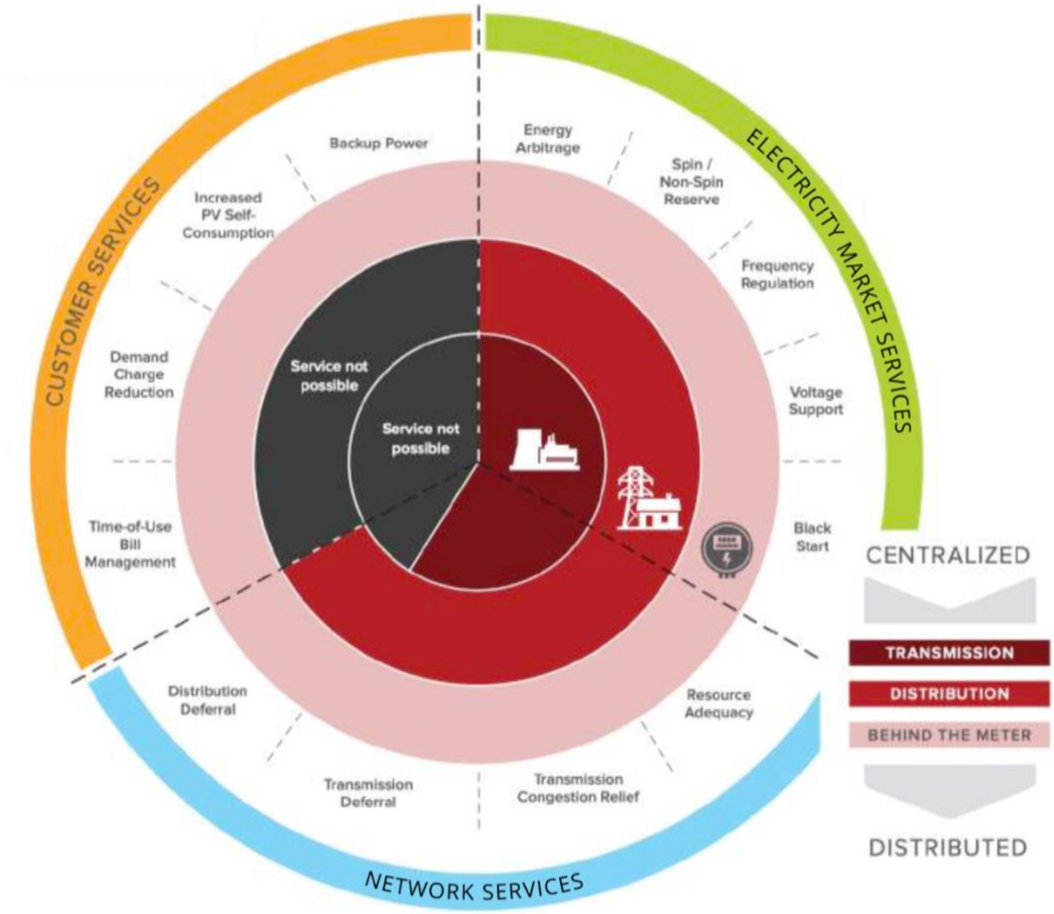

Figure 29 The Rocky Mountain Institute Battery Value Wheel (**RMI 2015**)

But in the case of community batteries, value may be highly subjective as proponents are not always measuring value as the direct financial benefits. For example, proponents may value backup power or solar hosting capacity greater than the financial benefits these services bring. As such, proponents of neighbourhood batteries will likely find that they must continuously and routinely revisit their drivers for a given community battery project to be clear on what services are of *most value* to them.

Table 10 shows the services that a neighbourhood battery can provide, a description of how they capture value (in which we have attempted to tie this back to financial value), the key stakeholders involved, and an indication of commercial value and technical and commercial complexity.

Table 10 - Potential services of a neighbourhood battery

	Service	Description	Value capture resulting from	Key stakeholders for value capture	Commercial value ($$$ being highest value)	Technical Complexity (10 being most complex)	Commercial Complexity (10 being most complex)
Network support	**Soft network capacity**	To improve load or solar hosting capacity, a battery may be used to supplement the capacity of a network transformer by discharging during times of peak demand and charging during times of peak generation. This is "soft" as a battery cannot indefinitely sustain this function due to its infinite size.	Deferred capital expenditure by DNSPs. No clear path for this value but potentially via a bilateral contract with a DNSP.	DNSP	$	3	6
	Voltage support	A battery provides voltage support to the network by providing Volt-VAR reactions or similar. This can support particularly low-voltage networks that have voltage issues due to solar export.	Services contract or similar with a DNSP	DNSP	$	6	8
	Back-up power	A battery provides back up power to one or more energy users during times when the grid is unavailable (e.g., during extreme weather events). This service is technically complex as it requires a section of network to be islandable.	Services contract with a local council or DNSP. It is unclear whether a DNSP will entertain these arrangements.	DNSP, local council	Unknown / nil but indirect value could be high	6	6
Social/environmental benefits	**Improve energy independence**	A battery charges with excess solar generation from a group of energy users common to a local transformer (i.e., net export) and discharges during times there is a net import at that transformer.	Value capture by default will come from wholesale market participation.	Retailer / Small Generator Aggregator	Nil, but indirect value could be high	2	3
	Reduce carbon emissions	The battery charges with electricity during times of low carbon intensity in the grid and discharges during times of high carbon intensity. The carbon reduction is the margin carbon savings from displacing the last generator in a carbon-intensity merit order. Given the novelty of this, the technical and commercial complex is very high.	Unclear. Potential from carbon credit generation but as far as Orkestra is aware this use case is technically and commercially unprecedented.	Carbon markets (e.g., ACCUs, Gold Standard, CERs etc)	$	8	8

	"Shared battery" as a service	In principle, a shared battery is an alternative to a privately owned battery installed "behind-the-meter" of a residence. A group of customers in connected in the same local network can use the neighbourhood battery to store excess solar generation. In practice under the currently regulatory framework, this requires a retailer is used to facilitate a commercial transaction between a neighbourhood battery operator and local customers. The retailer would need to be the financial responsible market participant (FRMP) to all parties. While technically straightforward as it has the same technical requirements as for improving energy independence, in our view this model is highly complex commercially to the point of being infeasible.	Tripart energy supply agreements between a retailer, battery operator and local customers where the local customers pay a virtual storage fee. Value capture would likely be facilitated by discount network tariffs for the local customers that provide discount charges for energy supply during times the battery is discharging. See Appendix C for more details.	Retailer, DNSP	$	2	10
Market services	**Wholesale market arbitrage**	A battery participates in the wholesale electricity market, charging during times of low energy market prices and discharging during times of high energy market prices. For the scale of a neighbourhood battery, the battery is classed as unscheduled generation and will be a price taker in the market.	Arbitrage of the wholesale electricity market facilitated by transactions with a retailer or small generation aggregator.	Retailer / Small Generator Aggregator	$$	4	3
Market services	**Contingency FCAS markets participation**	A battery participates in up to six different contingency FCAS markets. The contingency FCAS markets operating as capacity markets meaning a battery is paid on $/MW per hour for being available to respond to a market event, not for the event itself. Most neighbourhood batteries would be too small to participate in the FCAS market on their own right and there would need to be part of an aggregated group of assets participating together.	Bidding and dispatch by the Australian Energy Market Operator facilitated by a Retailer or MASP.	Retailer or Market Ancillary Services Provider (MASP)	$-$$$	6	6

11.4 What is the "value stack" of a neighbourhood battery

At current battery prices, most batteries are not economically viable if providing one service alone. Further, batteries are like a Swiss-army knife for the energy sector. They can and should provide multiple services to be fully utilised and economically optimised.

The provision of multiple services makes up what is called a "value stack". That is, a stack of different revenue streams that in total make up its entire value.

Not all services of a battery are complementary, as outlined in Table 10. Key factors that will determine whether services are complimentary are:

- **The ideal duration of the battery** – This is the length of time the battery can charge or discharge at *full power*[18]. Short duration batteries are best for situations that favour batteries with high power requirements and that can deliver a lot of energy in a relatively short period of time. For example, short duration batteries are ideal for wholesale market arbitrage, and contingency FCAS. Long duration batteries are ideal for soft network capacity, energy independence, and backup power.
- **The ideal state of charge of the battery** – This is a temporal attribute of the battery. Some services ideally require the battery to be fully charged, sometimes all the time, for example, a battery providing back up power. Other services require a battery to be fully discharged at the start of a day ready to charge with excess solar, for example when providing soft network capacity to improve solar hosting or increasing energy independence. To some degree, optimisation algorithms can be used to co-optimise the use of the battery but only when the battery can forecast what it might have to do. For example, when a battery will need to store solar is relatively predictable due to modern day weather forecasting. However, when a battery will be needed to provide backup is (generally) not predictable.

We have considered how reliably a battery can provide back-up power in Section 7.2.4 and in the project recommendations in Chapter 10.

[18] The duration of the battery is a bit of a misnomer, for example "1-hour battery" can be operated for much longer periods at lower power settings. The duration of the battery is commonly used as a proxy for power of the battery (measured in kilowatts [kW] relative to the capacity of a battery (measured in kilowatt-hours [kWh]). A short duration 1-hour battery is considered high power relative to a 4-hour battery which is considered as a low power, long duration battery.

11.5 How to think about neighbourhood battery ecomomics

In the process of undertaking our analysis (Part A), we had to think carefully about how we defined 'viability' of a neighbourhood or community battery. We have therefore outlined two versions of viability:

- **Financial viability:** The project is viable to the project proponent based on direct value capture alone (i.e., proponent $NPV>0). In our analysis, the value stack comprises of tariff arbitrage, wholesale arbitrage, and contingency FCAS.
- **Economic viability:** the project is viable to the broader community when direct and indirect values are considered (Adjusted $NPV>0). The indirect value might flow to a range of stakeholders and be non-monetary in nature to the proponent. In our analysis, the value stack comprises of direct value capture streams, plus soft network capacity value to the network, soft network capacity value to homeowners (via solar uptake), value of energy independence, and value of grid reliability improvements.

Assuming that our approach is robust and accurate, the outcomes for both financial and economic viability should determine whether a project should proceed to the next stage of delivery. The recommended approach for determining project viability is detailed in Table 11.

Table 11 – Recommended approach to determining project viability

Outcomes	Recommended next step
Financially viable: Yes ***Proponent NPV>0*** Economically viable: Yes ***Adjusted NPV>0***	**Project should proceed to next stage of delivery**
Financially viable: No ***Proponent NPV<0*** Economically viable: Yes ***Adjusted NPV>0***	**The project could make a case for grant funding based on the argument it is in the public good.** For the grant to be attractive to the project proponent, it needs to be at least the size of the shortfall in Project NPV to the project proponent.
Financially viable: No ***Proponent NPV<0*** Economically viable: No ***Adjusted NPV<0***	**The project should not proceed.**

Furthermore, for neighbourhood batteries to have long term prospects beyond the current round of government subsidies, there is ideally a pathway for neighbourhood batteries being financially viable. We would encourage proponents to consider this when selecting the services of their battery.

Box 10 – Battery Economics 101 (direct value capture)

Batteries are a capital investment that must make a return obtaining payments for:

- **Energy** – the ability to charge and discharge energy, charging at times of low prices and discharging at times of high prices. Revenue is generated by arbitraging the charging and discharging prices and is typically measured in terms of c/kWh.
- **Power** – the ability to offset power requirements, e.g., soft network capacity. This is typically paid based on the ability of a battery to sustain a reduction in power requirements and priced in terms of $/kW or $/kVA.
- **Capacity** – the ability to respond to unexpected events, e.g., contingency FCAS or back up power. This is typically paid on an hourly basis for the times a battery is available to respond and priced in terms of c/kW/h.

Ultimately all the revenue and energy transacting through the battery must exceed the upfront capacity cost of the battery. As a simple rule of thumb, proponents can conceptualise the relative average value of each service by reducing it to a c/kWh rate. For a given service, the average service value can be calculated as:

$$Average\ Service\ Value\ [c/kWh] = \frac{(Total\ battery\ revenue\ [\$] - Total\ battery\ operating\ costs[\$]) * 100}{Total\ energy\ discharge\ of\ the\ battery\ [kWh]}$$

This can be benchmarked against the Levelized Cost of Storage (LCOS) to determine whether a service is of value or not. It the average service value is less than the LCOS, then it will contribute to a negative return. The LCOS is calculated as:

$$LCOS\ [c/kWh] = \frac{Total\ capital\ costs\ [\$] * 100}{Usable\ capacity\ of\ the\ battery\ [kWh] * Warrantied\ number\ of\ cycles\ [\#]}$$

Where:

- the warrantied number of cycles is typically 1 per day for the life of the asset
- the usable capacity of the battery needs to account for battery degradation

Typical LCOS are in the range of 20 – 35 c/kWh, but 30 c/kWh is a reasonable benchmark. In the case of the Relectrify batteries modelled (with an assumed install price of $800), the LCOS is approximately 34 c/kWh (8-year life), but we have generously and very optimistically allowed for a 15-year life that reduces the LCOS to 20 c/kWh.

12 Key considerations for neighbourhood batteries

There are several key practical considerations for neighbourhood batteries:

- Where the neighbourhood battery should be located, including from both power system and geographical perspectives
- Which stakeholders that must be involved in each neighbourhood battery project
- How the battery should be controlled depending on the drivers of the project

There are trade-offs that must be considered when working through these practical considerations.

In addition to the above and complimentary to the consideration of stakeholders, the questions of who owns the asset and how the value is returned to the community is also key considerations. These considerations are considered in Chapter 14 -Recommended business model for CVGA neighbourhood batteries.

12.1 Where should neighbourhood batteries be located

12.1.1 Locations for a neighbourhood battery within the distribution network

There are four potential locations for a neighbourhood battery in a distribution network.

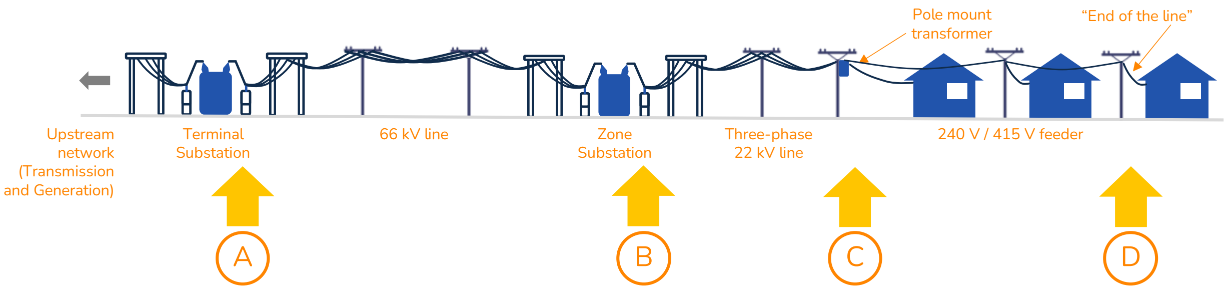

Figure 30 – Four options for locating a neighbourhood battery within a distribution network

A. In proximity to and on the downstream side of a terminal station – the point at which the high-voltage (66kV) distribution network commences (from the transmission network). A terminal station will serve in the order of hundreds of thousands of homes and businesses.
B. In proximity to and on the downstream side of a zone substation – the point at which the medium-voltage (22kV) distribution network commences. A zone substation will serve in the order of thousands of homes and businesses.
C. In proximity to and on the downstream side of a ground-mount or pole-mount transformer – the point at which the low-voltage (240V single phase / 415 V three phase) feeder commences. These transformers will typically serve up to 100 homes and businesses, but as little as a single premise.

D. At the “end of the line” – this is the end of the low-voltage feeder that serves the last home or business on that feeder.

As shown in Table 12, locating a neighbourhood battery in proximity to and on the LV side of a ground or pole-mount transform is the optimal location to be able to provide a full range of services. The only trade-off will be that the battery will be limited in its capacity to provide voltage support. Given the unknown value and commercial complexities of providing this service, we view it safe to dismiss the compromise.

Table 12 – Ease of service delivery by service for neighbourhood batteries located at various distribution network locations

	Service	A – Terminal Substation	B – Zone substation	C – Pole-mount transformer	D – End of the line
Network support	Soft network capacity	✗	o	✓	✗
	Voltage support	✗	✗	o	✓
	Back-up power	✗	✗	✓	o
Social/environmental benefits	Improve energy independence	✗	✗	✓	✓
	Reduce carbon emissions	✓	✓	✓	✓
	“Shared battery” as a service	✗	✗	✓	o
Market services	Wholesale market arbitrage	✓	✓	✓	o
	Contingency FCAS markets participation	✓	✓	✓	o

12.1.2 Suitable geographical locations for a neighbourhood battery

Ultimately a neighbourhood battery must reside on a title, easement, or public land. Given the interest of local municipalities to enable neighbourhood batteries, we would recommend to proponents that they seek to lease a parcel of road reserve or similar public reserve to locate a battery.

If the proponents ultimately seek Powercor (the distribution network service provider) to own the asset, then locating the asset within one of Powercor’s easements is likely to be the easiest option.

12.2 Which stakeholders are required for a neighbourhood battery project?

As highlighted in Table 10, there is a large variety of stakeholders that will be involved in each project. Below is a summary of how proponents should set expectations around stakeholders. This may impact decisions around who and how various stakeholders are involved in a project.

In general, engagements with stakeholders will be smoother and more transactional where proponents are seeking to provide services with their battery that conform to the stakeholders existing systems and processes.

Table 13 - Expectation management regarding various stakeholders

Stakeholder	Expected response to a neighbourhood battery project
DNSP (i.e., Powercor)	Regardless of the project, at a minimum Powercor will be involved for enabling the connection of the neighbourhood battery. For the connection, Powercor may ask for a power system study to be undertaken. We would recommend allowing up to 6 months for the connections process. Where the proponents of the project have an expectation of a DNSP to contribute resources or funds to the project (either as a capital contribution or ongoing revenue stream) outside any established process at a DNSP, proponents can expect long lead times (i.e., years) to establish a process for funding to flow. A DNSP may also require extensive power system studies and even control over an asset to provide funding.
FRMPs (i.e., Retailer or Small Generation Aggregator) and MASPs	Where proponents are seeking to provide services with a neighbourhood battery that involve *the sale of electricity*[19] to end-customers, e.g., providing shared battery as a service to households or businesses, proponents will need to engage the service of a Retailer. If Retailers are expected to be conduit to an exotic business model, such as virtual share battery as a service, proponents can expect long lead times (i.e., years) when working with retailers these models are well outside their core business and their business systems are typically very inflexible.

[19] Under Victorian energy regulations, the *sale of electricity* will be the key activity that will trigger the involvement of a retailer. If a neighbourhood battery proponent wishes to pass value to an end-customer via another mechanism, then using a retailer may be avoided.

	Where proponents require access to wholesale market to provide various services (e.g., improving energy independence, arbitrage, provide shared battery as a service or wholesale market arbitrage), proponents will need to engage the services of a financially responsible market participant (FRMP). A FRMP can be a Retailer or Small Generation Aggregator. From a business model perspective, if the simple task of providing market access is required, this is straightforward and transactional for these parties and lead times should be short (1-2 months). Where proponents are seeking to obtain access to the contingency FCAS markets, proponents will need to engage the services of a Retailer or Market Ancillary Services Provider (MASP). Again, this is relatively straightforward for these parties albeit not all Retailers and MASPs will offer this service. Due to the regulatory and technical requirements for these parties, proponents can expect lead times of 6-9 months.
Battery provider	There are two types of battery providers in Australia – system integrators (e.g., PowerTec) and battery OEMs[20] (e.g., LG and Tesla). Battery OEMs overall are interested in large volumes and in many cases are not interested in projects of volumes less than 1MW in size. We would recommend approaching system integrators and smaller battery OEMs.
Controls provider	Neighbourhood battery projects are still nascent, so the options for controls providers may be limited. Depending on the battery provider, the control solution may be packaged with the battery therefore Orkestra recommends that proponents select their battery provider first. In addition, not all controls providers (and control types) will be able to perform the services desired of a battery. Proponents should therefore be clear on what services they require when approaching controls providers.

[20] Original Equipment Manufacturers

13 Steps to progress the project to investment ready

Based on the Analysis presented in Part A, we do not recommend that CVGA progress any of the modelled projects towards investment. We have completed this chapter for generic reference purposes only.

13.1 Stages to advance a neighbourhood battery to implementation

Stage 1: Project formulation and assessment Is a neighbourhood battery a suitable solution in response to community drivers?		
a. Identify community needs	Understand priorities and community drivers for a neighbourhood battery solution.	Complete
b. Access data for modelling	Interval and network infrastructure data is required for projects that aim to solve network problems.	Complete
c. Technical and financial modelling (stage 1)	Confirmation that neighbourhood battery viably meets drivers. Recommendation of go/no-go, preferred project, system size and value stack.	Complete
d. Preliminary decision	Go/no go by proponent on whether to proceed.	Pending
Stage 2. Stakeholder & technology confirmation		
e. Project delivery partner	For a community-based organisation, we recommend finding a suitable technical and commercial delivery partner as early as possible to manage project delivery.	Not started
f. Confirm site	Confirm site availability, negotiate on terms and fees. To prevent delays here, the site owner should ideally be part of the journey from Stage 1.	Not started
g. Confirm revenue-access stakeholders	Confirm the delivery partners for accessing the proposed value streams. This may include an energy retailer, aggregator, market ancillary service provider, and the DNSP. A shortlist of controls software providers should be identified here as it is closely related to revenue access. Commercial terms should be negotiated and close to settled by this stage.	Not started

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h. Select battery hardware and installation partners	Select the battery technology for inclusion in the project. This could take the form of a tender, which might include engineering and installation contractors. Shortlisted control software providers in (g) can be confirmed here once technology compatibility is established.	Not started
i. Confirm ownership and investment model	The structure of who will own, operate, and invest in the asset needs to be finalised by this stage.	Not started
Stage 3. Investment due diligence		
j. Risk assessment	Detailed risk assessment scanning all project risks (technical, commercial, organisational, regulatory, and economic).	Not started
k. Detailed technical modelling	Detailed simulation of the proposed technology, considering proposed system sizing, degradation, and system configuration.	Not started
l. Detailed financial modelling and board pack	Detailed financial modelling of the proposed commercial model, updated with firm cost, and revenue shares. Include any third-party forecasts of market price datasets at this stage. Detailed sensitivity analysis of key risks. Preparation of cashflow and balance sheet for asset owner, including tax considerations. Board pack delivered to project proponents and any key investors.	Not started
m. Final investment decision	The final call on whether to proceed with the project is made at this stage.	Not started
Stage 4: Implementation - *Beyond scope of report*		

13.2 Identified project risks

Risk	Item	Likelihood	Severity pre-mitigation
Technical	Network connection delayed	Medium	Low
	Fire due to technical malfunction	Low	High
	Natural disaster (fire or flood)	Low	High
	Capacity degrades faster than expected	Medium	Medium
	Round-trip efficiency lower than expected	Low	Medium
	Project uptime is lower than expected	Low	Medium
	Key technical components break or face issues earlier than scheduled	Medium	Medium
	Control algorithms underperforming	Medium	Medium
Commercial	Partners renege on expected terms	Low	Medium
	Key stakeholders exit market mid-project	Medium	Low
	Administrative costs higher than expected	Low	Low
Economic	Market prices from wholesale and /or FCAS deviate from expected	Medium	Medium
	Battery capex costs increase before project reaches commissioning	Medium	Medium
	Battery OPEX and servicing costs increase during project	Medium	Medium
	Network tariffs substantially change over the project period	Medium	Medium
Organisational	Community organisation running project faces internal issues	Medium	Medium
	Administration operational costs of project not properly scoped	Medium	Medium
	Counterparty dispute with key stakeholder increases legal costs	Low	Medium
Regulatory	Market rules change, threatening key pillars of earnings	Low	Medium
	Planning approval rejected on grounds of safety, visual amenity etc	Medium	Medium

14 Recommended business model for CVGA neighbourhood batteries

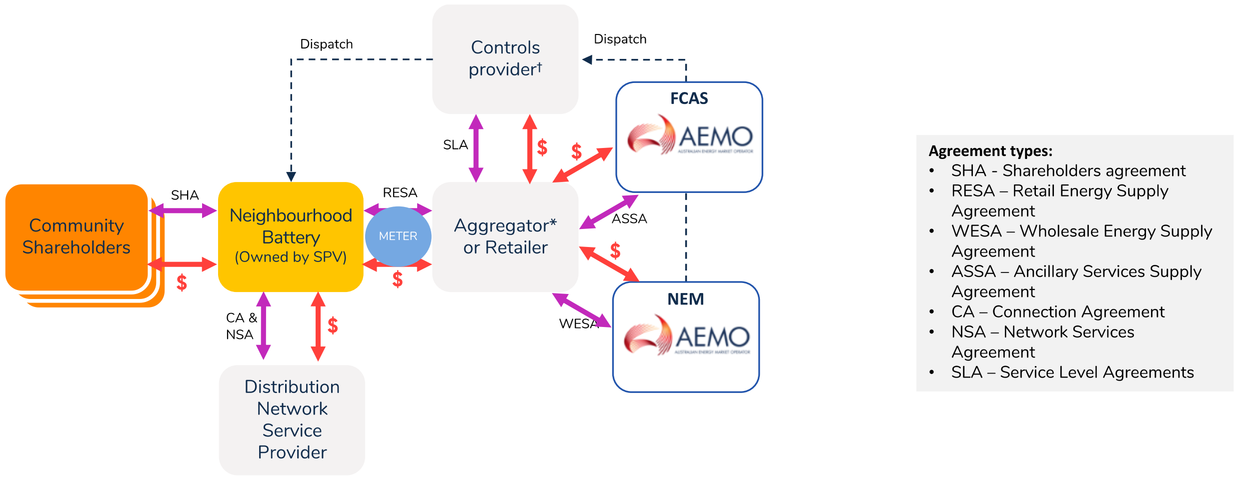
We have made our recommendation of a business model for CVGA and their partners based on a neighbourhood battery having the following value stack of services:

- Energy independence
- Soft network capacity
- Wholesale market arbitrage (limited to market events greater than $1000/MWh so as not to compromise soft network capacity)
- Contingency FCAS market participation (limited to market events greater than $100/MW/h, again so as not to compromise soft network capacity activity)

Our recommended business model to CVGA and its partners is:

- Any neighbourhood batteries developed conceived by this report should be owned by a special purpose vehicle that is partly or fully funded by the community.
- The development of an asset should be led by a specialist community energy developer with experience in developing special purpose vehicles (SPV) that enable community participation and ownership.
- Value should be returned to the community, at least initially, through dividend payments to the owners of the neighbourhood battery SPV.
- Asset management of the neighbourhood battery will likely need to be managed internally by whomever runs the SPV with maintenance, control, aggregation, and market access outsourced to the appropriate parties.

Figure 31 below provides a high-level outline of the commercial model that ties this structure together. The commercial model is complex, with many stakeholders involved in the project. In this model, the critical enabling party is an aggregator or retailer that can facilitate access to the wholesale market (NEM) and contingency FCAS markets.



*In this case the Aggregator would need to be an authorised Small Generation Aggregator (SGA) and Market Ancilliary Services Provider (MASP)
† Depending on the service model of the Aggregator or Retailer, they may have their own preferred controls provider or SPV could seek their own controls provider, thus having more control over the services and their priority.

Figure 31 – Commercial model for a neighbourhood battery owned by a SPV that provides network services to a Distribution Network Service Provider and participates in the wholesale and contingency FCAS markets.

In the sections below we have considered:

1. The potential ownership options
2. The potential development options
3. Options for returning value to the community
4. Operation options

In each section we have considered the relative strengths and weaknesses of each option.

14.1 Ownership options

There are five potential options for the ownership of a neighbourhood battery during its development and early operation. There is a potential sixth option to sell the asset to a specialist asset owner (e.g., an infrastructure or superannuation fund) later if the returns are attractive.

On the balance of the options below, we would recommend Option 2 – Community Group via an SPV as the best ownership option for a community battery. All the other parties listed below will be involved in the project in some way but are unlikely to be suitable owners for a variety of reasons discussed in the weaknesses section of the table.

Table 14 – Ownership options for a neighbourhood battery during its development and early operation.

Owner option	Strengths	Weaknesses
1. Council or local government	• Councils have ownership and control over the land typically needed for a neighbourhood battery. • Many local councils and councillors view the benefits of community batteries as highly desirable and are highly motivated to see them succeed.	• Ownership and coordination of neighbourhood batteries is not the core business for a local council. Critical decision making will likely be hampered by this. • The risk profile of neighbourhood batteries is likely outside the comfort zone of a council. • Councils may be suitable for a pilot, but they do not have the balance sheets to roll out these assets at scale.
2. Community group via SPV	• A community group is likely to lead most of the benefits returned to the local community. • Community groups may have lower expectations on returns. • Community groups that have experience developing community energy projects (e.g., Hepburn energy) will likely have the requisition experience to develop these projects.	• Significant administration is required for community organisations who wish to lead asset development. • Decision making within the group may be challenging given the highly complex nature of these projects. • There is not necessarily overlap between the investors in the project and the energy users in proximity to the battery that will indirectly benefit from the neighbourhood battery (e.g., via improved solar hosting).
3. Distribution network service provider (DNSP)	• A DNSP is well placed to own neighbourhood batteries with the potential to incorporate them into their regulated asset base. • As DSNPs can directly benefit from the network service that a community battery can provide (e.g., by deferring capital expenditure), it is easier to monetise the services of soft network capacity and improved grid reliability.	• DNSPs have their own investment priorities that will compete with a project conceived by a community group. They will judge the investment against other options available to them.

		• Ringfencing and other regulatory issues can limit the value stack options for a battery, specifically the ability to participate in energy markets. (There are examples where this has been overcome with ringfencing waivers issued by the regulator, but it is questionable whether is approach is scalable.) • There is no way for the community to directly participate in the battery ownership and value, and DNSPs may focus on the outcomes that serve their purposes rather than met community drivers.
4. Retailer	• A retailer is best placed to access the most value revenue streams of a battery (wholesale market arbitrage and contingency FCAS) • Retailers may be able (subject to the value created) to pass the benefits of a community battery more directly in the form of a community retail energy plan.	• To benefit from the neighbourhood battery, the community will be locked into a particular retailer for the life of the project. • It may be difficult to get a retailer interested in the project as it is well outside their core business and there may be insufficient project upside for them.
5. Specialist project developer/asset owner	• A specialist project developer/asset owner will likely be best placed to deliver a project efficiently and rapidly.	• Neighbourhood batteries are likely too complex and have too many stakeholders for most specialist project developers who will likely weigh up neighbourhood battery returns against those of utility-scale batteries. • No direct incentive or requirement for a specialist project developer to involve the community in a project.

14.2 Development options

Leading on from the above recommendation that a community group via SPV should own the asset, it is now important to consider who develops the asset.

There are only two options for who leads the development of the asset – either by the community group themselves or by enlisting the support of a specialist community energy project developer.

As a rule, we would recommend that unless the community group has previously developed a more straightforward community energy project (e.g., a wind or solar farm as is the case with Hepburn Energy), they should not attempt to develop the battery project themselves, given neighbourhood batteries are complex projects to develop.

For most community groups, we would recommend partnering with or contracting the services of a specialist community energy project developer. Options here include Hepburn Wind, Komo Energy, and other private companies with community project experience (for example Flow Power, who partnered with Repower Shoalhaven to deliver a solar farm). The community group may be forced to consider how to incentivise a developer to participate in the project, especially if the project is marginal or struggling to be financially breakeven. It may be that the community group will need to pay the developer upfront or on a time and materials basis.

14.3 Options for returning value to the community

Under the ownership model recommended – the neighbourhood battery should be owned by a community group via an SPV – the value of the project will be returned to the community via an issue of shares (likely tied to equity contributions) or debt funding arrangements, for example via the issue of convertible notes.

If the challenges of shared battery as a service (as discussed in Appendix C) are resolved, then a retailer may be able to pass benefits of a community battery back to the members of the community proximate the battery via a community retail energy plan.

14.4 Recommendations for meeting various operational requirements

As far as Orkestra is aware, there is currently no single organisation in Australia that the proponents of a neighbourhood battery could outsource to. As such, the asset management of the battery will likely need to be performed by the community group administering the SPV with various operational requirements of the battery outsourced to specialist providers.

Below are our recommendations for the various operational requirements of the battery. To be clear, the partner options have not been confirmed but based on Orkestra's knowledge of the services provided by their organisations.

Table 15 – Recommendations for the delivery of various operation requirements for a neighbourhood battery

Operational requirement	Recommendation	Partner Options
Market access	We strongly recommend against proponents trying to insource this operational requirement due to economies of scale requirements that are well outside that of a neighbourhood battery project. We recommend gaining access to the various energy markets – wholesale and contingency FCAS markets – by partnering with an authorised Market Customer (i.e., a retailer), or aggregator holding a Small Generation Aggregator (SGA) and Market Ancillary Services Provider (MASP) authorisations.	Retailer options: Momentum, Flow Power, Energy Locals, Aggregator options: Enel X
Maintenance	We recommend outsourcing scheduled and breakdown maintenance to an electrical contractor with experience maintaining batteries.	Nextgen Electrical

Operational requirement	Recommendation	Partner Options
Battery Control Provision	The battery control provider will be responsible for balancing and optimising the various services needs of the battery. It may be that the party that provides market access has a preferred supplier for the battery controls. The battery will also need some local control (e.g., to respond to frequency excursions and manage for soft network capacity) that will need to be integrated in the battery management system or provided by the controls provider.	Evergen, SwitchDIN

Appendix A. Analysis methodology

A.1 Simulation approach

Across all transformers we ran a total of 11,638 simulations considering:

- No battery and battery sizes of 36kW/120kWh, 72kW/240kWh, 144kW/480kWh and 288kW/960kWh. (CVGA specified Orkestra to use Relectrify batteries for its analysis.)
- Five cases of solar uptake – the current penetration then future penetrations case of 40%, 60%, 80% and 100%, filtering for cases where the current penetration exceeded any future solar uptake case. (See Section A.3 for details on our approach here.)
- Four different control profiles and value stacks as discussed in Sections 4.6.4 and 11.4.

For each simulation we calculated the following:

- 15-year NPV and IRR outcomes for the battery based on the future revenues and costs of the various services
- Energy independence by transformer at the current solar uptake and for future penetrations, calculating the net improvement of a battery. (See Figure 32 below)
- Calculation of soft network capacity determined as the maximum export from transformer with no battery installed versus the maximum export from the transformer with various batteries installed. (See Figure 32 below)
- How much solar energy would need to be curtailed where the minimum demand at the transformer (i.e., maximum export in kilowatts) exceeded the nameplate rating of the transformer.

Post-analysis, we selected several opportunities to assess their back-up power potential, determining the percentage likelihood of sustaining backup power for a given number of hours, should a random outage occur.

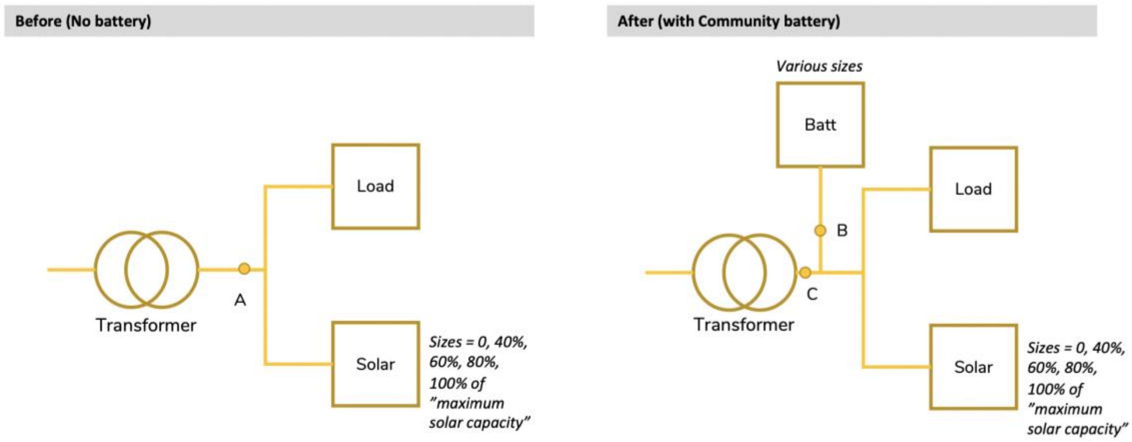


Figure 32 – Single line diagram showing the consideration of load and solar and the placement of batteries. We considered the economics of a battery measuring the energy flows metered at B and the energy independence uplift and network benefits metered at C versus A.

A.2 Commercial assumptions

Table 16 – Commercial assumptions (All prices at ex-GST)

Item	Assumption
Battery CAPEX	$800/kWh
Battery OPEX	2% of CAPEX p.a.
Simulation and analysis period	15 Years
Discount Rate	3%

A.3 Solar assumptions

As the data provided by Powercor provided:

- The number of customers exporting electricity (assumed to have solar)
- Aggregate export load profiles as measured at the transformer (Point A in Figure 32)

As this data omits the baseline solar installed (kWp) per transformer we have made assumptions based on average historical solar install data per postcode from APVI.

To determine the maximum solar uptake for each transformer in absolute terms we have applied the follow formula:

$$\begin{aligned} &\textit{Maximum solar capacity } [kWp] \\ &= \textit{Number of connected residential customers} * \textit{forecast residential solar size } [kWp] \\ &+ \textit{Number of connected commercial customers} * \textit{forecast commercial solar size} [kWp] \end{aligned}$$

To determine the new solar connected as a function of solar uptake with applied the following formula:

$$\begin{aligned} &\textit{New solar connected } [kWp] \\ &= (\textit{Maximum solar capacity } [kWp] * \textit{Percentage solar uptake } [\%]) \\ &- \textit{Baseline Solar installed } [kWp] \end{aligned}$$

Table 17 -Solar assumptions

Item	Assumption
Baseline residential solar size *average nameplate rating [kWp]:* • Ballan • Clunes • Glenlyon • Lyonville • Pomonal • Wheatsheaf	 • 5.2 kWp • 4.8 kWp • 4.7 kWp • 4.7kWp • 6.8 kWp • 4.7 kWp
Baseline commercial solar size *average nameplate rating [kWp]*	Same as residential
Forecast residential solar size *average nameplate rating [kWp]*	6.6 kWp DC (5kW AC)[21]
Forecast commercial solar size *average nameplate rating [kWp]*	19.8 kWp DC (15kW AC)[22]
DC-to-AC ratio	1.32
Solar generator output	1380 kWh per kWp[23]

[21] Aligned with Powercor connection limits for single-phase generation connections
[22] Aligned with Powercor connection limits for three-phase generation connections
[23] Aligned with STC generation assumptions

A.4 Battery assumptions

Table 18 - Battery assumptions

Item	Assumption
Battery vendor	Relectrify
Battery sizes	36kW/120kWh, 72kW/240kWh, 144kW/480kWh and 288kW/960kWh
Battery round trip efficiency	85%
Battery degradation	3% p.a.
Power factor	0.95
Energy reserved for FCAS	10 minutes at full discharge power
FCAS bid factor	100%: Each 1MW of battery capacity corresponds to 1MW of FCAS bid[24], corresponding to a droop factor of 0.7.

A.5 Control assumptions

A.5.1 Rules based algorithm assumptions

We have used rules-based algorithms to assess the value of Value Stacks 1 to 3 in this report (See Section 4.6.4).

Rules based algorithms operate as a set of hierarchical if-this-then-that rules that can be used in combination. They have no foresight and work exclusively on the basis the energy flows and market prices within a given interval.

Table 19 – Rules based control profile assumptions (All prices at ex-GST)

Item	Assumption
Used in Value Stacks 1, 2 and 3	
Base mode	Solar self-consumption – charge when export its sensed at the transformer and battery capacity is available.

[24] See AEMO Market ancillary services specification. For batteries under 1MW, AEMO will allow droop factors lower than 1.7 (corresponding to a bid factor of 41%). However, batteries will need to be aggregated and bid in together to exceed the 1MW minimum bid threshold.

Used in Value Stacks 2 and 3	
Delayed charging	Delay charging until 9am
Calculation of soft network capacity [kVA]	Maximum export pre-battery measured at midday *less* the maximum export post-battery measured at midday
Used for Value Stack 3	
Wholesale trigger - discharge	$1000 / MWh
Wholesale trigger - charge	$0 / MWh
FCAS trigger – all markets	$100 / MW / h
Action on FCAS trigger	Pause all other activity until the end of the interval

A.5.2 Optimisation algorithm assumptions

Orkestra's optimisation algorithm has been deployed for Value Stack 4 in this report. (See Section 4.6.4).

Orkestra's optimisation algorithm is a linear optimisation algorithm that determines within the dispatch foresight period the optimal charging and discharging of a battery to ensure it captures the most value from the various value streams it is controlling for. This algorithm is intended to mimic the best-in-class control algorithms for batteries available in the market today. To use a linear optimiser in a real-world application, the optimisation algorithm must also incorporate predictive algorithms for the load profile, solar profile, and markets to ensure the control appropriately accounts for future value (e.g., a battery might hold off on discharging into a particular valuable interval on the basis that another in the near feature is likely to be more valuable). As our linear optimiser has perfect foresight, we discount the various revenue streams to bring the revenues in line with the likely accuracy of these predictive algorithms that are tuned based on the feedback of leading controls providers.

Table 20 - Optimisation control profile assumptions

Item	Assumption
Wholesale arbitrage threshold	Battery avoids wholesale arbitrage where it cannot profit by more than $100/MWh.
Dispatch foresight	480 hours (dispatch performed 10 days at a time)
Discount on perfect foresight – wholesale arbitrage	25%

Discount on perfect foresight – FCAS	15%
Share of FCAS revenue to partners (MASP and controls provider)	20%

A.6 Forecast assumptions

Table 21 – Market forecast assumptions

Item	Assumption
Commencement date	January 2023
CPI	0%
Load escalation	0%
Solar escalation	0%
Wholesale market forecast	Historical data for Calendar Year 2021 applied to all years
Contingency FCAS	Historical data for Calendar Year 2021 applied to all years
Contingency FCAS escalator	-10%

A.7 Retail tariff Assumptions

Table 22 - Retail tariff assumptions (All prices are ex-GST)

Item	Assumption
Distribution loss factor	1.0
Marginal loss factor	1.0
Retail tariff	Generic wholesale passthrough tariff
Fixed charges	nil
Margin on wholesale rates - import	15%
Margin on wholesale rates – export	15%

Usage fees *Applies to all imported energy*	AEMO Ancillary Fee: 0.063 c/kWh AEMO Market Fee: 0.0549 c/kWh SREC: 1.1506 c/kWh LREC: 0.5302 c/kWh

A.8 Network tariff Assumptions

We have selected the Powercor non-distributor owned community battery trial network for our modelling.

This trial tariff offered by Powercor that was made available on the 1 July 2022 and until 30 June 2026 (4 years). We have assumed in our analysis (somewhat optimistically in the favour of community batteries) that the tariff will be available indefinitely. Note that Powercor is not making any money on this tariff, forecasting its FY23 revenue as nil. In our view this tariff is not sustainable for Powercor unless its trial determined the tariff delivered commercially favourable outcomes.

Table 23 - Network tariff assumptions (All prices are ex-GST)

Item	Assumption
Network tariff name	Powercor non-distributor owned community battery trial network tariff
Limitations	Applies to any battery-only site with a capacity of no more than 240 kVA connected to the low voltage network where the battery is not owned by the distributor.[25]
Fixed charges	45 c/day
Import rate	10am – 3pm: -1.5 c/kWh 4pm – 9pm: 25 c/kWh All other times: 0 c/kWh
Export rate	4pm – 9pm: -1.0 c/kWh All other times: 0 c/kWh

[25] We note that the largest battery size selected in our analysis is 48kVA above the threshold for this tariff. We have assumed that it will be possible to either derate the battery or seek an exemption.

Appendix B. Summary of challenges for this project

B.1 Identifying suitable locations

There is currently no transparent method for community groups to easily identify opportunities for neighbourhood battery projects. This project relied on anecdotal evidence from CVGA collected from the community to broadly direct its focus and then sought to obtain the transformer data.

B.2 Identifying and accessing available data

CVGA and Orkestra worked with C4NET to obtain the data for the project from Powercor. From the initial data request to the final data being made available was over 6 months. Further:

- It was very unclear what data was and was not unavailable from Powercor (there is no list of what data is available). There were cyclical cases of asking for data and not receiving what we needed thereby requiring re-requests occurring multiple times over.
- The data formats were unclear requiring multiple back and forth emails to clarify the nature of the data.
- There were different approval processes for the data. For example, it was possible to obtain interval data but not possible to obtain the location data for the transformers. So, while we have provided project recommendations for each village, we have no idea where the transformers are to physically qualify them!

B.3 The volume of data and processing required

While it is a strength of Orkestra's to process and analyse with large volumes of data, other organisations and community groups would likely have significant challenges processing data of this scale.

Appendix C. Commercial and regulatory challenges for “shared battery as a service”

As mentioned earlier in this report, we have excluded shared battery as a service from our analysis. As shared battery as a service are the “promised land” for neighbourhood battery, we know many readers of this report will be looking for further detail on this option and may be disappointed in the omission. We have thus provided some information on the key commercial and regulator challenges facing this service option.

If these challenges can be overcome some time during the life of the asset, then a neighbourhood battery may be able to provide shared-battery-as-a-service subject to its control. However, given that the key commercial and regulatory challenges relate to a fundamental premise of the grid - the grid being an essential service where all users of the grid within the area of a given distribution network pay the same price for their use of it, regardless of their location - we don’t recommend proponents hold their breath on changing regulation to enable this concept any time soon.

To illustration the challenges, we have provided a discussion on the difference in commercial model of a behind-the-meter battery installed at a home or business versus a shared neighbourhood battery.

C.1 Commercial models for behind-the-meter and neighbourhood batteries

As context for the simple economics discussed on the next page, below are the commercial model illustrations for behind-the-meter and neighbourhood batteries. The key difference is that behind-the-meter batteries (and associated solar) completely offset the costs of grid supply, whereas shared neighbourhood batteries must transact via the grid.

Behind-the-meter battery

In this configuration the solar and battery energy flows are not directly metered. Value is created by the solar and battery by offsetting the use of grid electricity by the end customer and reducing their retail electricity costs (and, indirectly, their network costs).

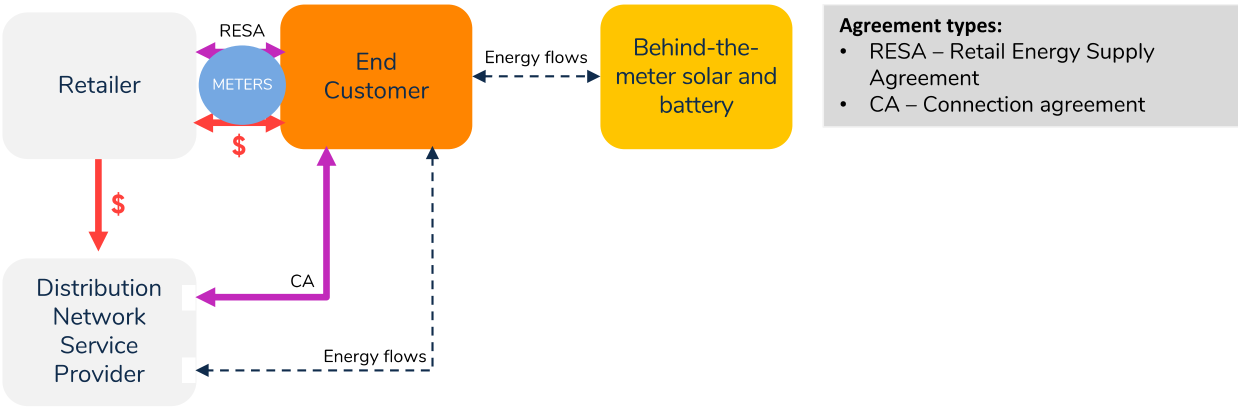


Figure 33 -Commercial model for behind-the-meter batteries

Shared neighbourhood battery

In this configuration, solar behind-the-meter offsets the end customer electricity usage. Excess solar is exported to the grid to be stored in the neighbourhood battery. The energy must passthrough the distribution network and be transacted by the retailer.

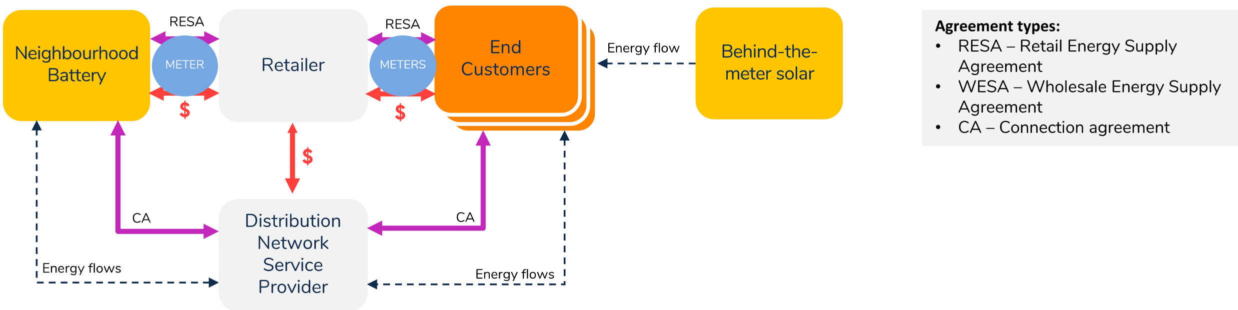


Figure 34 - Commercial model for shared-battery-as-a-service

Simple economics of behind-the-meter and neighbourhood batteries

The tables below demonstrate the key challenge for the shared battery as a service – the economics just don't stack up because too many parties are involved. Where a behind-the-meter battery will generate a saving for a home or business of ~25 c/kWh, a neighbourhood battery will generate a saving for the end customer of just 3 c/kWh with the battery making less than 5 c/kWh (even considering the new favourable Powercor community battery tariff). In both cases, the revenue is below the LCOS benchmark of 30c/kWh needed to financially breakeven (See **Box 10**), but neighbourhood batteries are not even close. The key issue is the energy must pass through the grid and be transacted by a retailer (twice!) with fees and margins paid each time. These transactions eat away at the revenue that would otherwise be paying for the battery.

Table 24 - Behind-the-meter battery – simple economics

Battery state	End Customers with battery
Battery charging @ 12pm *(storing excess solar generation)*	Opportunity cost: Solar FiT: -5.2 c/kWh (VDO)
Total during charging *(revenue is positive)*	-5.2 c/kWh
Battery discharging @ 6pm *(supplying stored solar generation)*	Revenue (avoiding cost): Peak tariff rate: 30c/kWh
Total during discharging *(revenue is positive)*	30 c/kWh
Total Arbitrage	24.8 c/kWh

Table 25 - Neighbourhood battery – simple economics

Battery state	End Customers	Retailer	Neighbourhood Battery
Battery charging @ 12pm *(storing excess solar generation)*	Revenue FiT payment: 5.2 c/kWh (VDO)	Revenue Energy sale: 5.2 c/kWh *plus* Margin @ 15%: 0.8 c/kWh Costs FiT payment: 5.2 c/kWh (VDO)	Costs Energy: 6 c/kWh *plus* Network charges: -1.5 c/kWh *plus* Reg & Enviro charges: ~2.5c/kWh
Total during charging *(revenue is positive)*	+5.2 c/kWh	+0.8 c/kWh	-5c/kWh
Battery discharging @ 6pm *(supplying stored solar generation)*	Cost Peak tariff rate: 30c/kWh *less* Comm. Batt discount @ 10%: - 3 c/kWh	Revenue Energy sales 27c/kWh Costs Energy – passthrough: 8.7c/kWh *plus* Network - peak tariff: 15.8 c/kWh *plus* Reg & Enviro charges: ~2.5 c/kWh	Revenue Energy: 8.7 c/kWh *plus* Network: 1 c/kWh
Total during discharging *(revenue is positive)*	-27 c/kWh	0 c/kWh	9.7 c/kWh
Total Arbitrage	-21.8 c/kWh (With saving of 3 c/kWh)	0.8 c/kWh	4.7 c/kWh

C.2 Regulatory barriers to shared battery-as-a-service

A regulatory change to enable shared battery as a service would likely involve either a move to locational based network pricing that would charge users of the grid based on the distance the energy to supply them had to travel through the grid (a model highly disadvantageous to rural customers) or some type of disaggregated distribution network pricing where customers would pay different prices for their network, likely based on the voltage level of the grid (See Figure 1 for an illustration of this). In both cases, retailers and distribution businesses would need root-and-branch changes to their business systems to accommodate the changes, so we view it highly unlikely that a change to these models would be fast, if they were to ever happen.