Regional and Remote Communities Reliability Fund Microgrid

# MyTown Microgrid

## Neighbourhood batteries in Heyfield – initial economic feasibility

Heyfield local energy options: techno-economic analysis

Milestone 5.3b – June 2023

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## Key support

Federation University Australia
Wattwatchers Digital Energy
AusNet Services
Heyfield Community Resource Centre
Latrobe Valley Authority

## About the project

MyTown Microgrid is an innovative, multi-year, multi-stakeholder project that aims to undertake a detailed data-led microgrid feasibility for the town of Heyfield (Victoria), built on a platform of deep community engagement and capacity building.

The project received funding under the Australian Government’s Regional and Remote Communities Reliability Fund Microgrids stage 1 funding round. It also received funding from the Latrobe Valley Authority as part of the Gippsland Smart Specialisation Strategy.

## Citation

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## Executive Summary

The MyTown Microgrid project is developing an innovative data-led approach to microgrids and local energy solutions, starting with the town of Heyfield in Victoria. Built on a platform of deep community engagement and capacity building, the project is also creating the knowledge and tools to make it faster, easier, and cheaper for other regional communities to understand the proposition for microgrids, and for complementary local energy solutions for their towns.

This report outlines the economic potential of neighbourhood batteries for Heyfield stakeholders, including solar and non-solar householders, energy retailers, and the network business. It summarises the findings from modelling community battery scenarios for a residential LV feeder in Heyfield and at a commercial premise (the pub). The findings from this study are expected to inform a more detailed business case study if the community wishes to proceed towards implementation. This would include installation quotes and agreed rates with the battery operator.

## What is a neighbourhood battery and why is it important?

A neighbourhood battery is a battery storage system that is installed in a local community at a scale to serve its whole neighbourhood. It can be designed to provide backup power, to support the electricity grid and/or to shift renewable energy to times when it can be used. These batteries are typically connected to LV networks and charged during periods of excess generation from local renewable sources or from grid imports when prices are low. They are discharged during periods of high demand or when prices are high.

The size for neighbourhood batteries depends on the specific project and its primary purpose. The capacity may be dictated by their location on the network, for example, batteries on residential feeders are typically sized from 100 to 500 kW. Battery size will also be determined by the amount of energy the battery will be called on to absorb or deliver, and sizes from a few hundred kilowatt-hours (kWh) to several megawatt-hours (MWh) can be expected.

The importance of neighbourhood batteries lies in their ability to help address some of the challenges associated with integrating renewable energy into the grid. By storing excess renewable energy, neighbourhood batteries can increase the amount of rooftop solar that can be installed locally and allowed to export and reduce the likelihood of excessively high voltages. By discharging at times of high energy demand, neighbourhood batteries can defer upgrades to local transformers, can reduce the need for fossil-fuel-based peaking power plants, support grid stability, and increase the amount of solar which may be installed without causing network issues.

If community batteries are designed to provide backup power, they can help ensure critical infrastructure retains power when there is a grid outage, thereby improving resilience. This requires additional investment in inverter technology, automated switching and battery design and is not possible in all situations.

Front-of-the-meter (FTM) batteries are typically owned and operated by utilities and/or communities and are designed to support the grid as a whole. Behind-the-meter (BTM) batteries are co-located with an existing energy user and typically owned by individual customers. They can be integrated into premises to provide backup power or to reduce reliance on the grid. A BTM battery can also serve as a community asset if it is managed as part of a broader community energy solution, typically alongside an investment in renewable energy. Both types of batteries can provide important benefits.

## How did we evaluate the economics of neighbourhood batteries?

We evaluated the potential for community FTM batteries to gain an economic return for the community without impacting customer bills, for residential BTM batteries to reduce customers' bills, and for a BTM commercial battery to both benefit the customer and the community. We undertook the modelling using the energy planning software Gridcognition.

We considered three main cases: (i) an FTM battery on the residential feeder (100 kW/ 200 kWh), (ii) a fleet of 60 residential BTM batteries (3 kW, 3.3 kWh each), and (iii) a BTM battery at a pub as a promising commercial premise in terms of load shape (a range of sizes for the 2-hour battery from 5 kWh to 100 kWh).

We assumed that the FTM residential feeder battery would be operated by the retailer but owned by the community, with any profit assigned to the community. In the case of BTM residential batteries, we assumed ownership by each household. For the BTM commercial battery we assumed the community would finance the battery and receive any profit, but that the value would be shared with the commercial customer. We note that there are a number of options for the administrative arrangements and have tried to identify the potential value to be gained in each.

### *FTM battery*

We used aggregated smart meter data for the relevant feeder from AusNet Services. This included the net load and controlled load consumptions, as well as solar exports. The analysis was conducted for a 100 kW/ 200 kWh battery, assuming the retailer operates the battery. It was also assumed that the retailer makes a surcharge of 1c/kWh on battery throughput. All analysis was over 10 years, with battery cell replacement at the end of 5 years operation. The five modelled scenarios were no battery (the base case), a battery operating under standard network tariffs, and three different trial tariffs that other DNSPs have offered (currently there is no AusNet Services trial tariff, although one is in development).

### *BTM batteries – individual and a fleet*

We modelled the economics of battery installation for individual customers with solar, and for a fleet of residential BTM batteries on the same feeder with the total equivalent size to that of the FTM battery. We modelled 3 kW, 3.3 kWh batteries. Based on preliminary simulations, this battery capacity was deemed suitable for typical residential solar PV systems in Heyfield, which usually have a capacity of around 3-5 kW.

All analysis is over 10 years (battery replacement isn’t needed in that time as the batteries cycle less in the BTM situation). The analysis was only carried out for homes with solar, as there is no positive economic impact of a battery without solar. Currently, there are 31 houses with solar on the feeder of interest. Therefore, the analysis was carried out under the assumption that the number of houses with solar will increase significantly to 60, with all installing the 3 kW, 3.3 kWh battery.

We adopted a data-led modelling approach building on Milestone 5.1, *Typical residential load profiles for Heyfield*. The load and sub-load profiles and household solar PV profiles were derived from a fleet of 107 household-level devices installed within a total of 96 houses in Heyfield (out of approximately 700 houses in the town)[a]. The analysis of BTM batteries was undertaken for various customer types in terms of hot water (standard resistive and heat pump) and space heating systems (with/ without HVAC).

### *BTM battery at the pub*

The third case study examined the potential use of BTM batteries in a commercial setting, specifically at a pub, which has higher energy consumption demands compared to residential properties, and a large solar system. A range of battery sizes, from 2.5 kW/ 5 kWh to 50 kW/ 100 kWh, were analysed for their suitability and economic viability for installation at the pub to improve energy management and hence reduce power bills. The analysis assumed a third party operates the battery on behalf of the community, with the value shared 70% to the battery operator/ community, and 30% to the pub. We obtained NMI net load and solar exports data from AusNet Services. To evaluate the performance of the battery, solar generation data was also required, for which synthetic solar generation data was calculated using a solar tool[b], as actual solar generation data was not readily available.

## Modelling results

### *Economic viability of FTM battery versus residential BTM battery fleet*

Figure E1 shows the analysis by stakeholder in the cases of the 100 kW/ 200 kWh FTM battery under various tariff settings and an aggregated fleet of 60 BTM batteries for the average customer, each rated at 3 kW, 3.3 kWh.

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[a] Mohseni, S, et al. (2023). Residential load profiles for Heyfield, Victoria.
[b] Smith, H. (2023) solarcalculator.xlsx - Excel Spreadsheet. Changing Weather. Available at: www.changingweather.com.au/calculators  The tool was used to convert NASA insolation data to solar generated.

The comparisons are made with respect to the network charges, the retail margin, FCAS revenues, an approximation of wholesale energy costs, the technology cost associated with community batteries, as well as the net profit or loss for the community (for the BTM batteries, the community net profit or loss is the impact on the customers with batteries installed).

In accordance with normal market operation, the retailer receives the entire electricity bill and is liable for the network and environmental charges, as well as the energy costs. The retailer is responsible for the FTM battery operating and capital costs and receives a throughput charge for the battery, while the individual customers are liable for the individual battery capital costs in the BTM modelling.

As the figures show, the BTM batteries perform better economically and need less grant support. A grant of about 50% is required to break even, compared to 75-95% in the FTM case. However, the grant is going to private individuals in this case and may not bring the same community benefits.

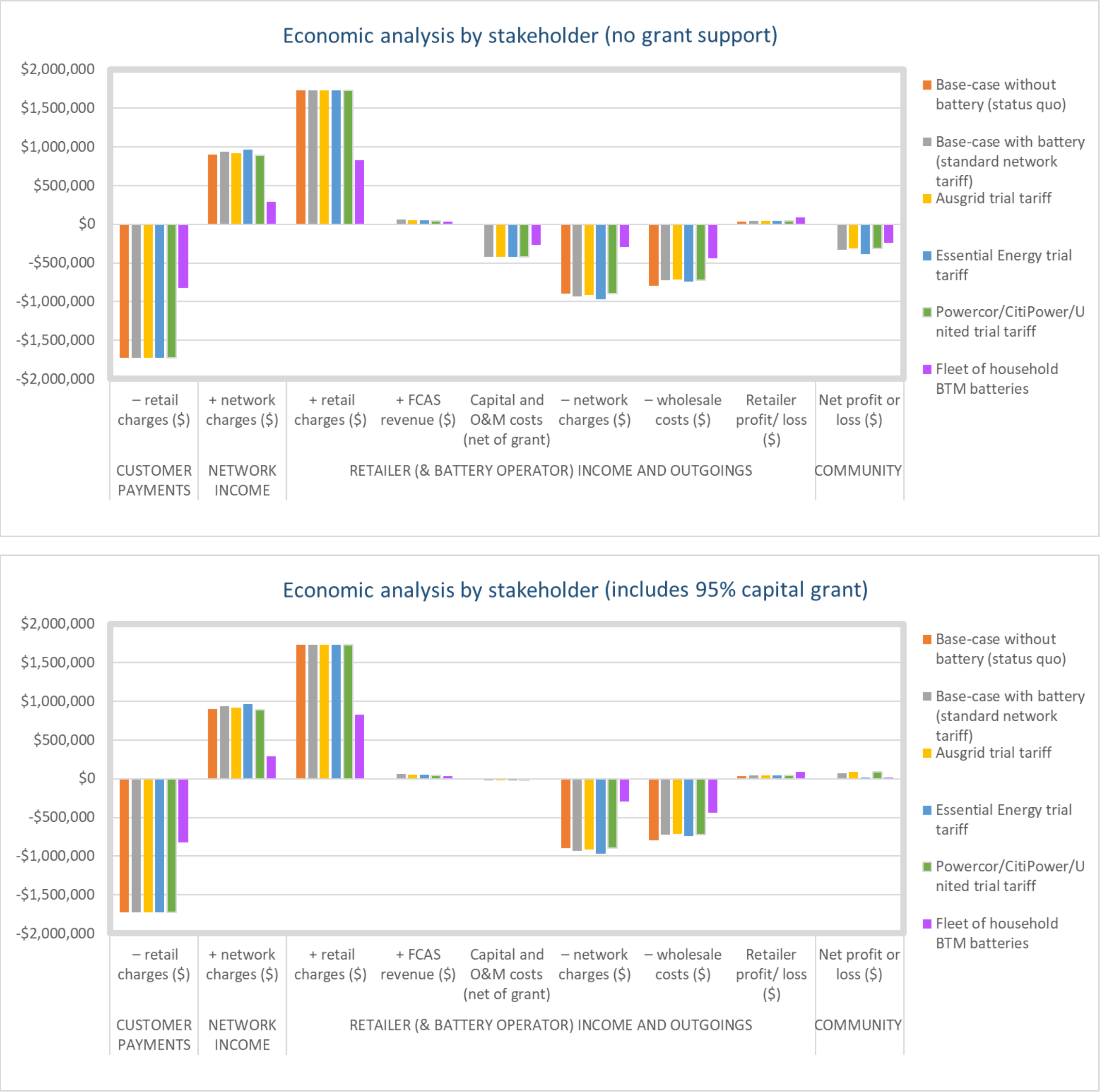
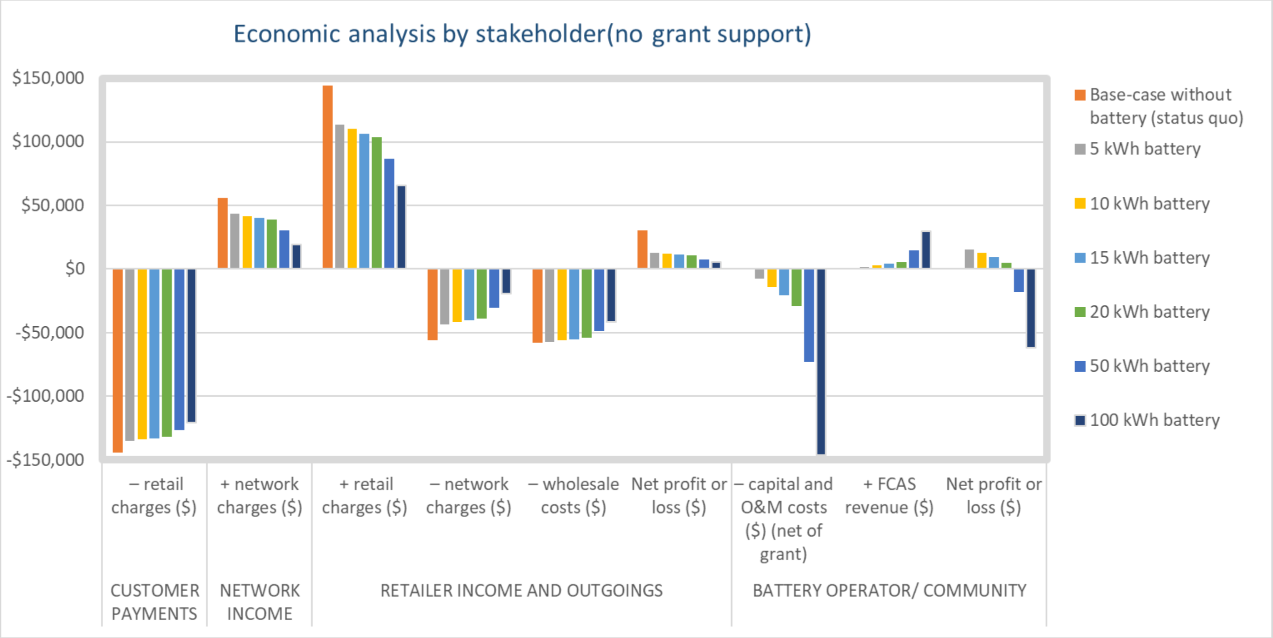


*Figure E1 Comparison of FTM with BTM fleet of batteries on same feeder with different grant levels (10-year project life) Notes: the FTM battery is 100 kW, 200 kWh, the BTM batteries have a total capacity of 180 kW, 198 kWh. In the FTM case there are 101 customers, 31 with solar; in the BTM fleet there are 60 customers with solar and batteries.*

### *Economic viability of the BTM battery at the pub*

Figure E2 shows the analysis by stakeholder for a range of BTM battery sizes at the pub. Larger battery sizes may provide higher levels of resilience due to their increased capacity to store energy and support critical loads during outages. However, beyond a certain point, the benefits of increased battery size may begin to diminish, as larger batteries may become more expensive and less efficient, leading to reduced economic viability. Larger battery sizes may be more appropriate for sites with higher energy demands, higher excess solar available, or greater resilience needs, while smaller battery sizes may be sufficient for sites with lower energy demands, lower excess solar, and lower resilience needs. Ultimately, the appropriate battery size and configuration for a given site will need a trade-off on a range of factors, including energy consumption patterns, resilience requirements, and economic considerations.



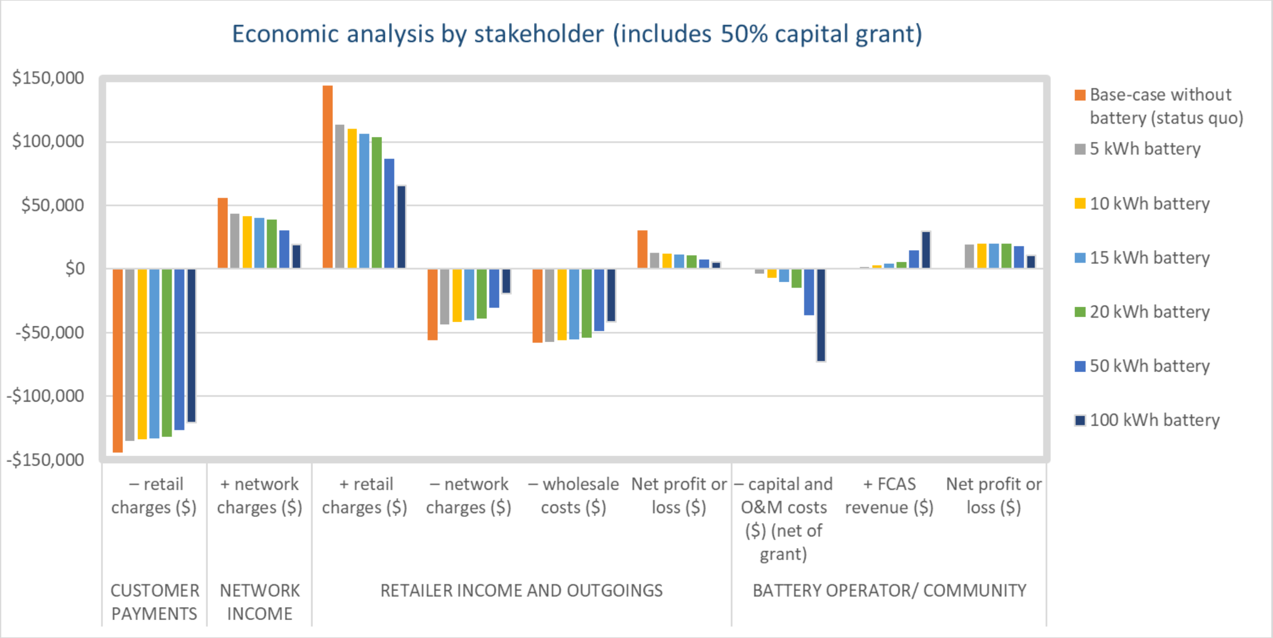


*Figure E2 BTM batteries at the pub – impact on customer bills considering different levels of grant support (all batteries have 2-hour energy storage, 10-year project life)*

## Conclusion and recommendations

Based on the analyses and findings presented, none of the batteries is economic without subsidy, with the potential exception of small batteries (10 kW/ 20 kWh) behind the meter at commercial premises.

The most economic case is undersized batteries at the pub, followed by the BTM fleet on the residential feeder, followed by the FTM neighbourhood battery on the residential feeder. The first two cases are likely to require grants of 50% and upwards, while the neighbourhood battery is likely to need grants 80% and upward in order to give a return to the community and/or the customers.

As none of the cases is likely to be economically compelling without a grant, the optimum case depends primarily on community objectives. Battery operation is determined partially by the aspirations of the project and business model, so firmer definition of these objectives is needed to determine the optimum battery size and operating mode prior to undertaking the business case. It might be useful for Heyfield to trial all three battery types, at least to a more detailed business case, as different applications achieve different aims. In all cases where the battery is a shared community asset, it is likely that fixed costs (including set up costs) are significant, so sharing these costs among a fleet of batteries is advised.

The following steps are recommended to create an energy storage pathway for Heyfield:

- Identify wider project objectives to use as assessment criteria for different battery cases. Objectives could include, for example, increasing hosting capacity to reach 100% RE, enabling load growth, enabling fast EV chargers.
- Undertake detailed business cases for:
    - A fleet of commercial BTM batteries (potential size 20-50 kWh)
    - A 50 kW/ 100 kWh FTM neighbourhood battery
    - A fleet of subsidised BTM residential batteries to go to existing solar homes or homes installing solar

Based on the analysis presented for the commercial premise of interest, a strategy for implementing BTM battery systems in residential and commercial settings may involve starting with a relatively small battery coupled with an appropriately sized solar array to maximise the cost-effectiveness of the system while developing the institutional arrangements to manage community energy projects and provide a degree of resilience. As energy demands increase, the system sizes could be gradually increased for both the solar array and the battery storage to provide greater energy independence and resilience, while balancing economic considerations. This approach could help ensure that the system meets the site’s energy needs and resilience requirements, while maximising cost-effectiveness. However, the most effective pathway depends to a large extent on community aspirations for the project and for energy in general.

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## List of abbreviations

| Abbreviation | Description |
|---|---|
| BTM battery | Behind-the-meter battery |
| DNSPs | Distribution network service providers (e.g., AusNet Services, PowerCor) |
| EV | Electric vehicle |
| FCAS | Frequency control ancillary services |
| FIT | Feed-in tariff |
| FTM battery | Front-of-the-meter battery |
| HVAC | Heating, ventilating and air conditioning |
| kW | Kilowatt |
| kWh | Kilowatt hour |
| LV | Low voltage |
| MW | Megawatt |
| MWh | Megawatt hour |
| NMI | National metering identifier |
| Solar-PV | Solar photovoltaic |
| TOU | Time-of-use |

# 1 Introduction

The Heyfield MyTown Microgrid project is undertaking a detailed data-led microgrid and energy solutions feasibility study for the town of Heyfield (Victoria), built on a platform of deep community engagement and capacity building. Over the three-year duration, the project will develop the knowledge and tools to make it faster, easier, and cheaper for other regional communities to understand microgrids and other energy solutions for their community.

The MyTown Microgrid project provides a range of reports and resources, including documenting Heyfield's journey to explore a microgrid and other local energy solutions[c].

Across industry, government, new energy market players, and the community as a whole, there is an increasing interest in shared storage, and particularly community-scale batteries. Recent studies and community battery trials have demonstrated that they can have techno-economic benefits, provided they are sized and located using well-designed optimisation-based approaches.

A growing body of literature has shown that community batteries can help address the emerging issues from the increasing penetration of distributed solar PV generation (typically rooftop). They can add value by:

- providing ancillary services to the wider utility network,
- smoothing peaks in the load on the distribution network,
- improving power quality by smoothing the variable output of distributed PV systems,
- keeping the LV grid operational during outages or maintenance,
- deferring/ deterring network upgrade investment, and
- increasing the PV and EV hosting capacities.

However, existing network tariffs have been widely recognised as a key barrier to the deployment of community batteries. Figure 1 illustrates the overall concept of a community battery.

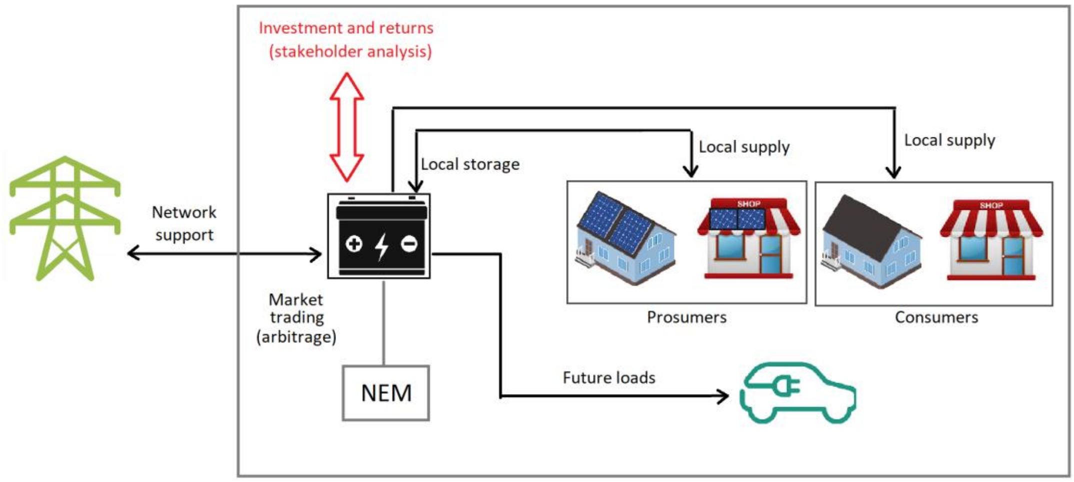

*Figure 1 Illustration of how a community battery works*

In the context of energy solutions for communities, the terms front-of-the-meter (FTM) and behind-the-meter (BTM) refer to the location of energy storage systems in relation to the electricity network (see Figure 2). FTM battery storage systems are connected directly to the grid and are typically larger, while BTM systems are installed on-site, either in homes or commercial premises. While both types of systems have advantages and challenges, the focus of this study is mainly on the economic viability of an FTM battery versus a fleet of smaller scale household-level BTM batteries, as well as larger BTM batteries at commercial premises.

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[c] https://www.uts.edu.au/isf/explore-research/projects/mytown-microgrid-heyfield-victoria

Appropriately sized BTM batteries can improve energy resilience and create cost savings through increasing self-consumption, peak shaving and other applications. Commercial sites typically have higher energy consumption than residential properties and can therefore benefit from larger batteries.

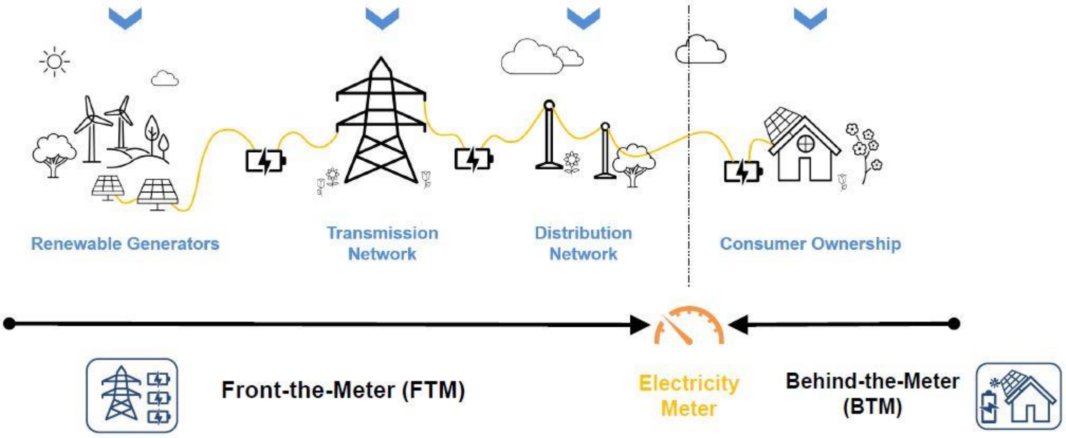

Figure 2 Comparison of FTM and BTM batteries[1]

## 1.1 Overall aim and objectives

The overall aim of this report is to evaluate the economic viability of alternative types of community batteries in Heyfield, Victoria. The analysis examines the potential value produced by a community battery on a low voltage (LV) residential feeder, how the return compares to a fleet of BTM batteries on the same feeder, and the potential value of a BTM battery at a commercial premise. The specific objectives are:

- To assess the potential value streams generated by a community battery, including arbitrage and network services such as frequency control ancillary services (FCAS).
- To evaluate the impact of alternative network tariffs on the economic viability of a community battery. Specifically, a range of battery tariffs recently introduced by various DNSPs aimed at maximising consumption within the LV feeder and minimising peak demand, are tested.
- To compare the return on investment (ROI) of a community battery with that of a fleet of behind-the-meter batteries of equivalent total capacity.
- To provide insights and recommendations for different stakeholders, including solar and non-solar consumers on the LV feeder and the network business, on the economic viability and potential benefits of a community battery.

## 1.2 The scenarios

Three main scenarios have been considered:

1. An FTM battery on the residential feeder: A single FTM battery is installed on the residential feeder. in an appropriate location and used to provide energy storage and distribution services to households on the feeder. This scenario is being evaluated as the primary option for a centralised energy storage solution that can provide returns to the community.
2. A fleet of BTM batteries at solar PV-equipped houses: A fleet of BTM batteries is deployed with the same total energy capacity as the FTM battery. The BTM batteries would be installed at individual households on the same residential feeder.
3. A BTM battery at a solar PV-equipped commercial premise: BTM batteries of varying sizes are installed at a commercial premise; specifically, a pub. The scenario assumes the community is the investor, with benefits shared between the community and the customer.

This analysis seeks to provide insight into the potential benefits and challenges of each approach and enable stakeholders to make informed decisions regarding the deployment of a community battery.

# 2 Methodology

This section presents the methodology for evaluating the economic viability of FTM and BTM batteries, and covers:

- The time series data inputs and how these were obtained and processed
- The trial tariffs used for the FTM battery assessment
- The sources of value for the three cases
- How the participant-level value flows were configured.

The modelling was undertaken using Gridcognition software[d].

## 2.1 A data-driven approach

This report is based on three main case studies, which aim to evaluate the economic viability of deploying varied energy storage configurations. Each case study involves different time-series datasets (generation and consumption) from different sources.

For the FTM battery on the residential feeder, we used aggregated smart meter data for the relevant feeder collected from AusNet Services. This included the net load and controlled load consumption, as well as solar exports. As controlled tariff and off-peak TOU rates were virtually the same, we were able to readily add up main (net) and controlled load components to calculate the underlying load.

For the corresponding fleet of BTM batteries on the residential feeder, we used the typical load and sub-load profiles developed in *Milestone 5.3a, Typical residential load profiles for Heyfield*[2]. They were used to construct representative scenarios of different solar household types in terms of their space and water heating systems, as well as their access to a controlled load tariff to evaluate the comparative economics of a residential BTM battery.

For the BTM battery at the pub, we used the NMI net load and solar exports data. To evaluate the performance of the battery, solar generation data was also required, for which synthetic solar generation data was generated using a solar calculator tool[e] for converting NASA insolation data to solar generated for any location and panel orientation, as actual solar generation data was not readily available.

Wholesale prices and contingency FCAS datasets were obtained from the National Electricity Market's data for Victoria for the time period for which we had load data (July 2021 to June 2022)[3].

## 2.2 FTM battery: Community battery trial tariffs

In addition to a battery operating under standard network tariffs, we tested three different trial tariffs that other DNSPs have offered (currently there is no AusNet Services trail tariff, although one is in development). Table 1 provides details on the standard network tariff, the TOU energy community battery trial tariffs tested, as well as the peak demand-based community battery trial tariff tested. All of these trial tariffs have a local use of system (LUOS)-based tariff regime/structure at off-peak hours, which means free consumption and export when using the local system (i.e. network downstream of the 415v transformer) and an off-peak charge for consumption at all other times.

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[d] Gridcognition Simulation & Optimisation Engine integrates rigorously tested parametric models for multiple kinds of energy resources, a billing-grade pricing and rating engine for commercial calculations, and an advanced optimiser to accurately represent the control system that will orchestrate and optimise the energy resources. For more information, see the following link: https://gridcog.com/

[e] Smith, H. (2023) solarcalculator.xlsx - Excel Spreadsheet. Changing Weather. Available at: www.changingweather.com.au/calculators

*Table 1 Network tariffs used in the FTM battery analysis*

| | Fixed charge | Off Peak / solar soaker (Essential Energy only) | | Peak | | Shoulder | | Critical times |
|---|---|---|---|---|---|---|---|---|
| **AusNet Services Standard tariff** (NAST12 –) | 34.2658 cents per day | 10pm – 8am weekdays<br>The entire weekends | | 9am – 9pm weekdays | | Not applicable | | Not applicable |
| | | 4.7115c/kWh import | 0c/kWh export | 19.3182c/kWh import | 0c/kWh export | | | |
| **Essential Energy Community Battery Tariff** | $15.8085 per day | 9am – 3pm<br>9pm – 7am | 10am – 2pm | 5pm – 7pm | | 7am – 9am<br>3pm – 4pm<br>8pm – 9pm | | Not applicable |
| | | 2.7850c/kWh import<br>$2.3064/kVA/ month demand charge<br>0c/kWh export | 0c/kWh import or export<br>$0.65/kW/month 0 kW to 3 kW export capacity, $1.45/kW/month above 3 kW | 5.0624c/kWh import<br>$10.2257/kVA/ month demand charge | 10.8012c/kWh export | 4.1956c/kWh import<br>$9.2519/kVA/ month demand charge | 0c/kWh export | |
| **Powercor/ CitiPower/ United Energy Community Battery Tariff** | 45 cents per day | 10am – 3pm | | 4pm – 9pm | | All other times | | Not applicable |
| | | -1.5c/kWh import | 0c/kWh export | 25c/kWh import | -1c/kWh export | 0c/kWh import | 0c/kWh export | |
| **Ausgrid Community Battery Tariff** (EA962/EA963) | $1.72/kW/ month (Balancing charge paid to the network to make battery revenue neutral if supporting network) | Anytime (other than critical peaks) when adding load to the transformer* | | | | | | **Up to 10 4-hour events per year** |
| | | Import 1.6c/kWh<br>*this will not apply when local PV exports are greater than local load, as in this situation load on transformer will not increase<br>Export 0c/kWh | | | | | | **Peak demand**<br>Import: 141c/kWh<br>Export: -141c/kWh<br>**Peak solar export**<br>Import: -75c/kWh<br>Export: 75c/kWh |

## 2.3 Existing sources of value for FTM and BTM batteries

To better understand the economic performance of BTM and FTM batteries, it is useful to compare the energy flows that contribute to their sources of value. Two graphs are provided in Figure 3 that illustrate the key differences in energy flows for BTM and FTM batteries.

While both types of batteries can potentially leverage improved self-consumption, energy arbitrage, and participate in FCAS markets, they do so to different degrees and with different applications. BTM batteries are primarily designed to provide onsite storage and consumption of energy generated from onsite renewables, reduce peak demand charges, and provide backup power during outages. FTM batteries, on the other hand, are primarily designed to provide grid-scale services, such as frequency regulation, peak shaving, and energy arbitrage by charging during periods of low demand and discharging during periods of high demand.

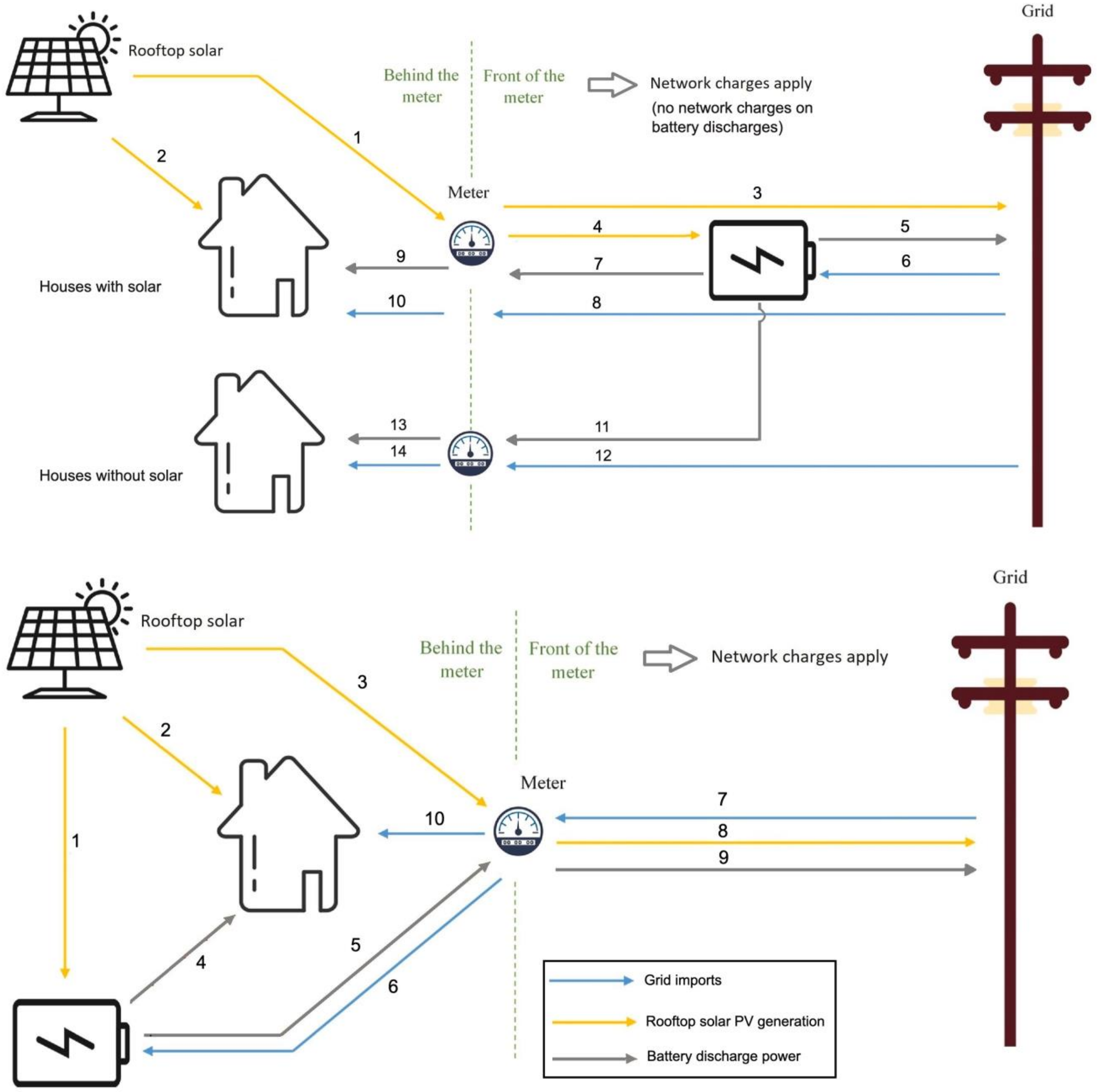

*Figure 3 Comparison of the energy flows for FTM and BTM batteries.*

*Reproduced from "Rezaeimozafar, M., Monaghan, R.F., Barrett, E. and Duffy, M., 2022. A review of behind-the-meter energy storage systems in smart grids. Renewable and Sustainable Energy Reviews, 164, p.112573."*

Table 2 provides a comparative summary of the potential sources of value for FTM and BTM batteries and their relative importance in each case. It also illustrates the corresponding energy flows for each value category using the numerical values assigned to each flow in Figure 3.

*Table 2 Comparison of sources of value for FTM and BTM batteries, associated energy flow directions, and their relative importance (note the corresponding energy flow diagram).*

| Sources of value | FTM batteries | | BTM batteries | |
|---|---|---|---|---|
| | *Energy flow direction(s)* | *Importance* | *Energy flow direction(s)* | *Importance* |
| Increased self-consumption | 1 → 4 → 7 → 9<br>1 → 4 → 11 → 13 | Medium<br>(at neighbourhood-level) | 1 → 4 | High<br>(at customer-level) |
| Arbitrage | 6 → 5<br>6 → 7 → 9<br>6 → 11 → 13<br>1 → 4 → 5 | High | 7 → 6 → 5 → 9<br>7 → 6 → 4<br>1 → 5 → 9 | Low |
| FCAS | 5 | High | 5 → 9 | Low |

Both FTM and BTM batteries provide value to their owners and the broader community in a number of ways.

### Increased self-consumption

Both FTM and BTM batteries can potentially be used to increase the self-consumption of solar energy – or other variable renewable energy – generated by end-consumers (albeit to different degrees). That is, storing onsite generated electricity during periods of low demand (e.g., during the day when solar panels are generating power) and then using onsite electricity during periods of high demand (e.g., in the evening when solar production decreases and household demand increases). By storing excess solar energy during the day and using it during peak evening hours, households can reduce their reliance on grid electricity and save money on their electricity bills.

*FTM batteries*

For FTM batteries, increased self-consumption is a potential source of value, although it is less direct compared to BTM batteries. In our analysis, we defined the value of increased self-consumption for FTM batteries as the difference between the FIT rate paid by the retailer for exported solar energy and the wholesale electricity price at the time of export, minus the battery throughput charge. This difference reflects the avoided cost of purchasing wholesale electricity for the retailer, and it is typically a considerably smaller value compared to the savings from increased self-consumption for BTM batteries.

*BTM batteries*

Increased self-consumption of solar energy is a key source of value for BTM batteries, as it allows households to use more of the electricity generated by their solar panels on site, reducing their reliance on grid power and saving money on energy bills. In our analysis, we found that for BTM batteries, the value of increased self-consumption is defined as the difference between the FIT paid for exporting excess solar energy to the grid and the per kWh charge for grid electricity, inclusive of all charges. This difference represents the avoided cost of purchasing grid electricity and can be substantial depending on the location and tariff structure.

### Arbitrage

In the context of battery storage, arbitrage typically involves buying electricity from the grid when prices are low (e.g., during off-peak hours), storing it, and selling it back to the grid when prices are high (e.g., during peak hours), thus taking advantage of the price difference.

Arbitrage can also refer to the practice of storing the local excess generation when prices are low and exporting back to the grid later during more remunerative hours. Alternatively, arbitrage can involve buying electricity from the grid when prices are low, storing it, and discharging it to meet local demand when prices are higher and there is insufficient locally generated electricity available.

*FTM batteries vs BTM batteries*

It is important to note that the ability to engage in arbitrage depends on a variety of factors, including accessibility to the market, and the size and capacity of the battery system. In the case of BTM batteries, the potential for arbitrage may be significantly more limited than in FTM batteries due to the smaller size of the systems and the need for aggregators to give them enough scale for participation in the relevant market.

#### Frequency control ancillary services (FCAS)

FCAS are a set of fast-acting services that are used to regulate the frequency of the power system within narrow limits. This is necessary because the frequency of the power system is a key indicator of its stability, and any deviations can cause disruptions or even blackouts. That is, these services are used to help maintain the stability of the grid by providing fast responses to sudden changes in supply or demand. It is assumed that batteries participate in contingency FCAS markets by maintaining the state of charge and receiving payments for being on standby.

*FTM batteries vs BTM batteries*

Both FTM and BTM batteries can provide FCAS to the grid, while FCAS opportunities are generally more lucrative for FTM batteries due to their larger size, BTM batteries can still provide some FCAS services and help to support grid stability. That is, similar to arbitrage, in the case of BTM batteries, the potential for arbitrage may be significantly more limited than in FTM batteries due to their smaller size, as well as the need for aggregators to give them enough scale.

Overall, both FTM and BTM batteries provide a range of value streams to the stakeholders, including the broader community. By utilising these batteries, households can increase their self-consumption of solar energy, save money on their electricity bills, and support the stability of the grid.

## 2.4 Participant-level value flow configurations

This section illustrates the specific value flow configuration used in each of the three models.

Figure 4 shows the interactions of customers, the retailer, and the network in the FTM battery model set up. Figure 5 illustrates the value flow configuration for the BTM batteries on the residential feeder model set up, while Figure 6 summarises the interactions of the involved participants for the BTM battery in the pub model set up.

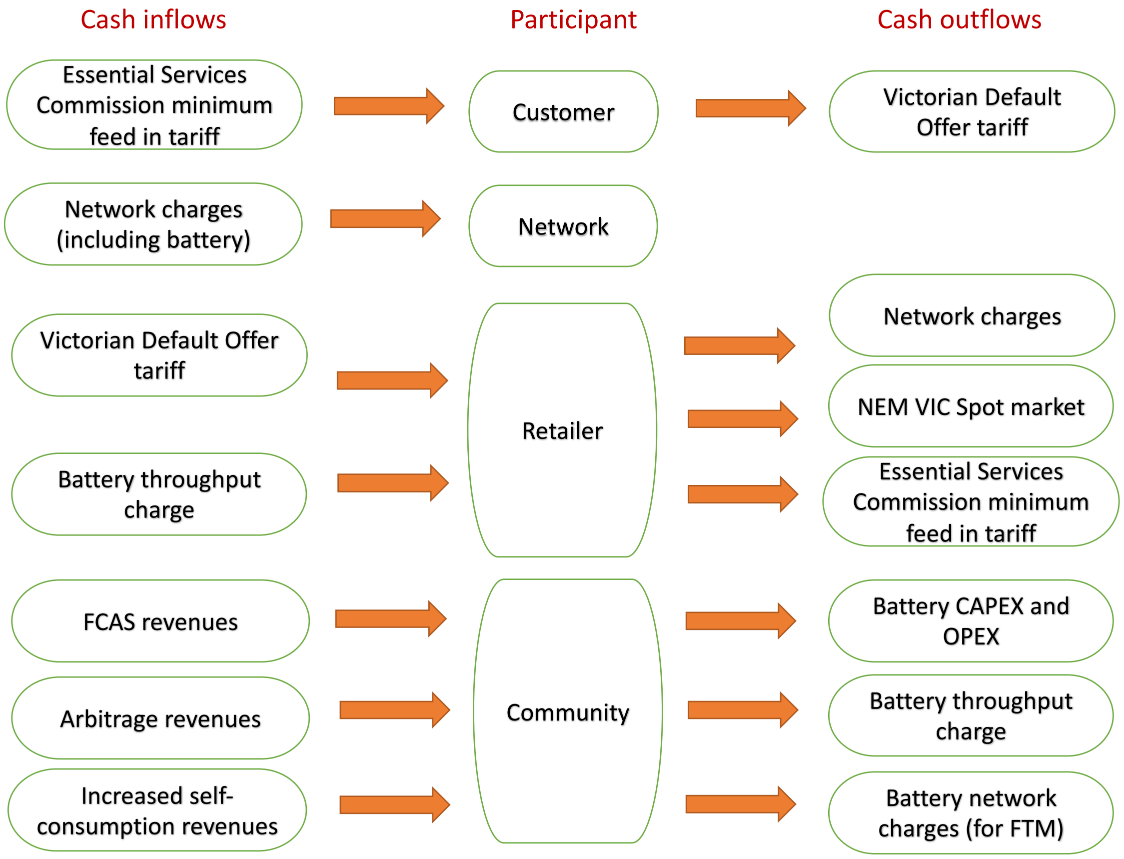

*Figure 4 Value flows in the FTM battery model (includes community value)*

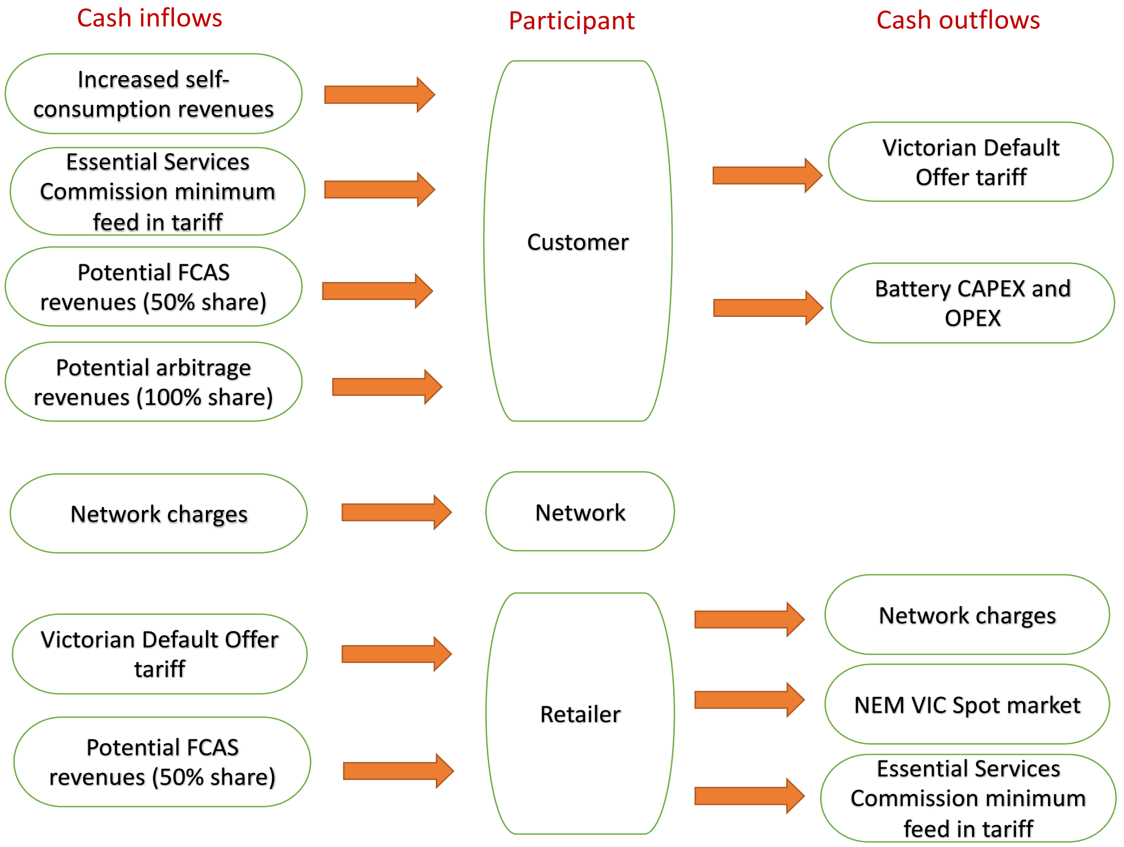

*Figure 5 Value flow in the residential BTM battery model (note no community value flow)*

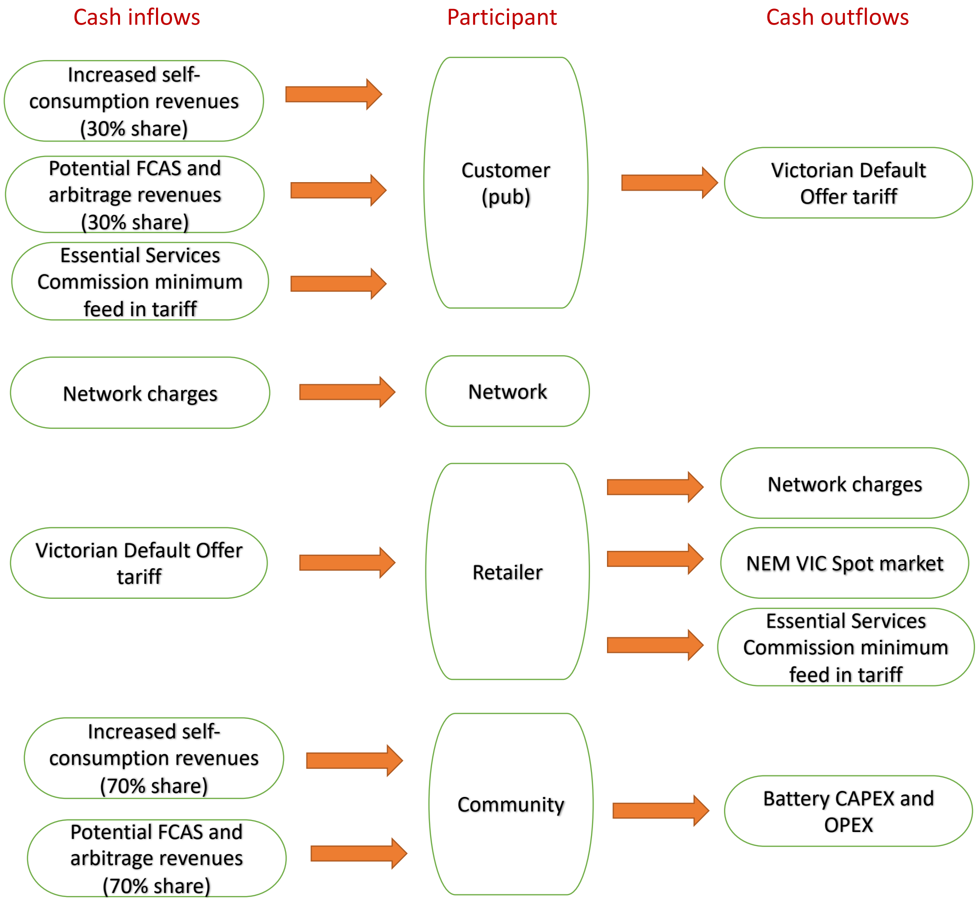

*Figure 6 Value flow in the commercial BTM battery model set up (includes community value)*

# 3 Case study 1: Front-of-meter battery on a residential feeder

## 3.1 Overview

This case study examines the installation of an FTM battery on a residential feeder and the potential benefits it can provide to various stakeholders. The main objective is to analyse the economic viability of deploying an FTM battery in this context, with a focus on the role of trial network tariffs in supporting the associated developments. The study assumes that customers are on time-of-use (TOU) pricing, and the business case for the battery storage system is evaluated based on its ability to generate revenue through improved self-consumption, grid arbitrage and FCAS market revenues. The stakeholders involved in the study include the network business, the retailer, residential customers (both with and without solar), and the community as a whole – as the owner of the shared neighbourhood battery asset.

The five scenarios studied are no battery, a battery operating under standard network tariffs, and three different trial tariffs that other DNSPs have offered (currently there is no AusNet Services trail tariff, although one is in development).

## 3.2 Key inputs and assumptions

Table 3 summarises the key assumptions used in this study for the tariffs, the cost of the battery asset and associated enablement technologies, and the general modelling assumptions.

The load profiles and costs have been assumed to remain steady through the project lifetime, and the modelling has not included the potential for load flexibility or energy efficiency.

While a number of the assumptions used are simplified for practical reasons, the modelling detail is deemed sufficient to derive meaningful insights for this step in the community battery feasibility process.

*Table 3 Summary of key assumptions – battery on residential feeder (front of the meter)*

| Parameter | Value(s) used in modelling | Comment/ source |
|---|---|---|
| Residential electricity tariff | 0.4081 $/kWh peak<br>0.1965 $/kWh off-peak<br>Service charge: $1.2994/ day | Victorian Default Offer Rates[4] for AusNet Services area |
| Network tariff (non-battery energy flow) | 0.2291 $/kWh 3pm-9pm weekdays<br>0.0477 $/kWh all other times<br>Service charge: $125.07/ year | Enables calculation of stakeholder outcomes to include network business and retailer |
| Standard network tariff (battery charging energy flows) | 0.1932 $/kWh 9am-9pm weekdays<br>0.0471 $/kWh all other times<br>Service charge $125.07/ year | Standard network tariff (small business time-of-use) in the AusNet area – NAST12[5] |
| Feed in tariff[f] | $0.05/kWh | Minimum feed in tariff set by Essential Services Commission[6] |
| Battery type | Lithium ion | Currently the most available and cost-effective. |
| Battery capacity | 100 kW<br>200 kWh | Discharge duration = 2 hours |
| Expected lifetime (excluding battery cells) | 10 years | Non-battery cell components such as power conversion system, cables, cooling systems, and other equipment |
| Battery capital cost (initial) | $305,680 | Excludes battery cell replacement; for a list of the components see Appendix A Inputs and assumptions for battery costs |

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[f] Note that the current premium FiT of $0.60/kWh expires in 2023 or 2024 depending on the start date, and therefore, not considered in this study.

| Parameter | Value(s) used in modelling | Comment/ source |
|---|---|---|
| Capital cost of replacing battery cells | $88,768 | The discounted cost of replacement at the end of year 5 uses the cost reduction from CSIRO's GenCost report[7] |
| Battery O&M cost | $16/kWh/ year | Includes labour, materials, and equipment to operate the system[8] |
| Battery round-trip efficiency | 90% | The ratio of the energy output from a battery compared to energy input during a full charge-discharge cycle. |
| Battery throughput cost | 1c/kWh | Assumed the retailer makes a surcharge of 1c/kWh on battery throughput. |
| FCAS market exposure | 100% | The battery can offer all available electricity capacity to provide FCAS (ancillary) services to the market, rather than just selling energy on the spot market. |
| Time period of the original data used | One year from July 2021 to June 2022 with hourly resolution | NMI data obtained from AusNet Services |
| Project lifetime/ planning horizon | 10 years | January 2024 to December 2033 |
| Discount rate | 4% | The recommended discount rate for Commonwealth infrastructure projects[9] |

The methodology is as described in Section 2.3. Note that in the FTM battery case, battery-related network charges only apply to charging the battery. That is, in accordance with Figure 4, the retailer pays for the transport of energy for charging the battery, while customers pay the retail tariff for any imports under the net metering mechanism[g], which includes standard network tariffs. Customers who generate solar power can receive FIT for the excess energy they export back to the grid, including the excess power used to charge the battery.

In this setting, the retailer’s net profit or loss is defined as the algebraic sum[h] of retail charges (positive, as it is an income), network charges (negative, as it an expense), and wholesale charges (negative) in the baseline case of without battery, plus associated battery throughput charges in the cases with battery. That is, relevant battery throughput charges (positive) are added to the baseline revenue or profit of the retailer in the absence of a battery.

The community’s net profit or loss is then calculated as the algebraic sum of retail charges (positive), network charges (negative), and wholesale charges (negative), FCAS revenues (positive), the battery’s capital, cell replacement, and annual O&M costs (positive), minus the retailer’s profit or loss calculated above.

### 3.3 Economic results by stakeholder

Figure 7 shows the stakeholder analysis for the FTM battery without any grants.

The base-case without battery shows a total net profit or loss of $0, as expected. This validates that without a battery, the model is not showing the community generating any additional income or loss.

Comparing the base-case to the battery with trial network tariffs, we can see that the deployment of a battery under the standard network tariff leads to a net loss of $33,300 per year. Under the Ausgrid trial tariff, the net loss is reduced to $31,400 per year; under the Essential Energy trial tariff, the net loss rises to $38,800 per

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[g] Net metering is the measurement that is used when solar power is consumed on a customer’s premise, and only the unused or excess solar electricity gets exported into the grid.
[h] Algebraic sum refers to the total amount that results from adding positive and negative numbers together. It is also known as the net sum or the sum of all the numbers taking into account their signs (positive or negative).

year; and under the Powercor/CitiPower/United trial tariff, the loss is reduced to $31,300 per year, the lowest loss overall.

Without grants, the financial viability of deploying the FTM battery in this context is not attractive at all, as can be seen from the significant negative net profits for all the network tariffs investigated. Furthermore, we can observe that the battery operation surcharge is a non-negligible cost component, ranging from 2.66% to 3.31% of the net loss, depending on the associated network tariff.

The modelling shows that the battery is not economic without a grant. The break-even point is at a grant of between 75% and 95% (or 75 - 80% excluding the Essential Energy trial tariff).

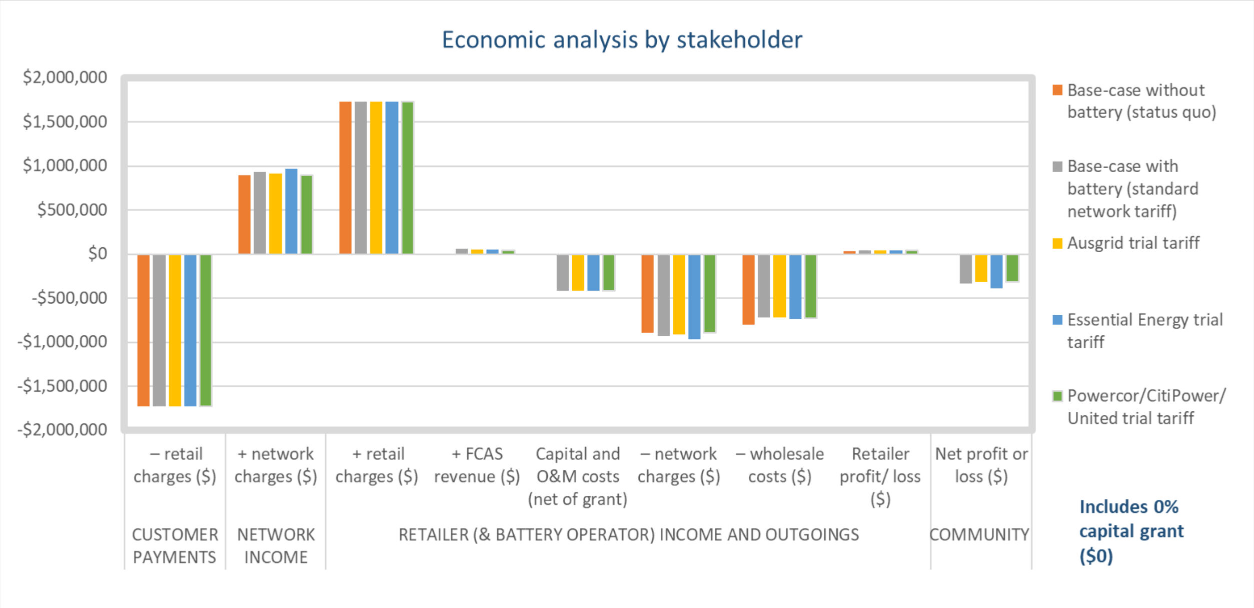

*Figure 7 FTM 100 kW/ 2-hour battery on residential feeder – without grant*

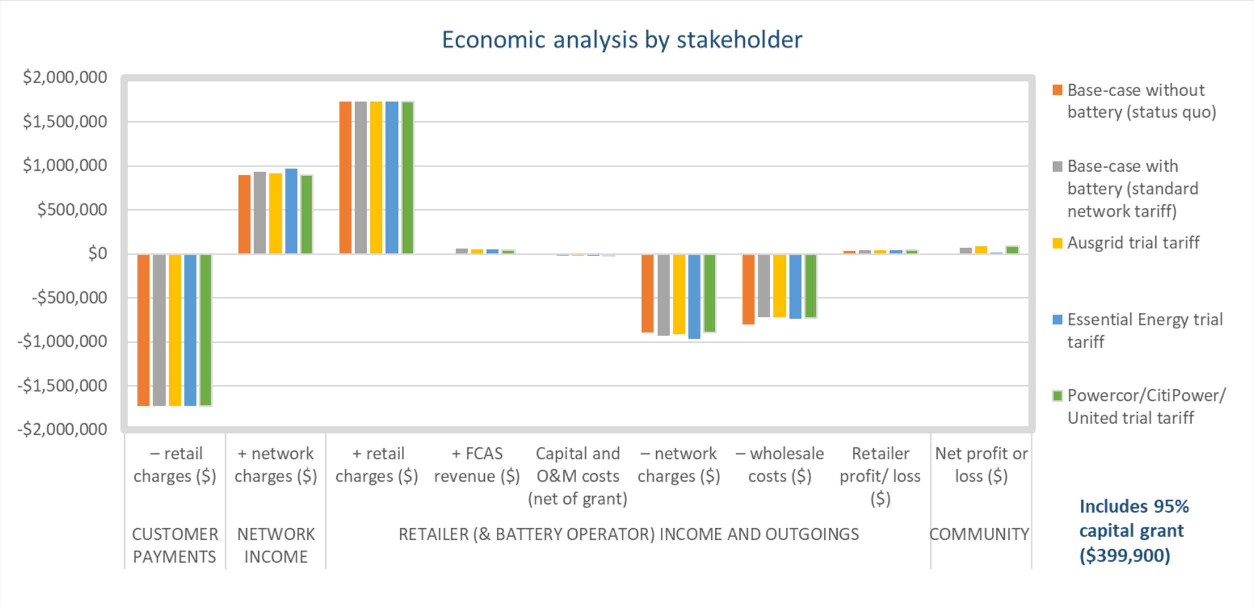

*Figure 8 FTM 100 kW/ 2-hour battery on residential feeder – with 95% grant*

Figure 8 shows the stakeholder analysis for the FTM battery with 95% grant of capital costs (about $400,000). This would result in estimated community income of $1,200 - $8,700 per year. The project shows a positive net profit for all the scenarios in this scenario, ranging from a net profit of $1,200 per year (Essential Energy trial tariff) to $8,700 per year (the Powercor/CitiPower/United trial tariff). The standard network tariff would generate a net profit of $6,600 per year.

The battery operation surcharge ranges from 12% to 85% of the net profit, indicating the important impact of the arrangements regarding battery operation on overall profitability.

## 3.4 Load shape analysis

In order to realise the value streams identified, it is imperative that robust forecasting systems are in place. The software we have utilised assumes so-called perfect foresight on time-series data. That is, it anticipates future loads, generation, and prices, in order to gain the best value possible from the battery (this is discussed in greater detail in the load shape analysis in **Error! Reference source not found.**). This would not be the case in practical situations, so accurate forecasting combined with good management would be needed to realise the value streams shown here.

## 3.5 Conclusion – residential feeder FTM battery

Overall, these results suggest that the financial viability of deploying an FTM battery in the context of a residential feeder depends heavily on the associated trial network tariffs and the availability of grants. This highlights the critical role that grants can play in making neighbourhood batteries financially viable.

# 4 Case study 2: Behind-the-meter batteries on a residential feeder

## 4.1 Overview

This case study examines the installation of BTM batteries at individual households on the residential feeder. To evaluate the economic viability of deploying a fleet of BTM batteries, we have conducted a detailed analysis of various solar PV-equipped customer categories in terms of hot water (standard resistive and heat pump) and space heating systems (with/without HVAC). By analysing different customer categories with unique load shapes, we aim to provide a comprehensive understanding of the economic implications of deploying a fleet of BTM batteries, which may better represent the overall load shape of the community of interest. This will enable us to better assess the impact of different customer categories on the economic viability of the project and identify the potential value streams and benefits that a fleet of BTM batteries can provide to different stakeholders, including the network business, the retailer, and solar customers on the LV feeder. It is important to note that we did not include customers without solar PV systems as there is no positive economic impact of a battery without solar.

The primary objective of our analysis was to evaluate the impact of deploying a fleet of BTM batteries on electricity bill reduction and self-consumption improvement for individual customers. In addition, we assessed the potential for participation in the FCAS market and the potential for grid arbitrage. It is important to note that the individual customers will own the batteries, and the focus of our analysis was on the potential value streams and benefits that BTM batteries can provide to these customers.

Furthermore, we chose to focus our analysis on customers who are on the TOU tariff as they are likely to benefit the most from BTM batteries due to the potential variability in their energy usage patterns throughout the day. TOU tariffs incentivise customers to shift their energy consumption to off-peak periods when electricity prices are lower, and battery storage can help them achieve this by storing excess energy generated during the day for use during the evening peak period.

The eight solar-equipped customer type scenarios studied are (i) element hot water/ HVAC, (ii) element hot water/ no HVAC, (iii) HP hot water/ HVAC, (iv) HP hot water/ no HVAC, (v) controlled element hot water/ HVAC, (vi) controlled element hot water/ no HVAC, (vii) controlled HP hot water/ HVAC, and (vi) controlled HP hot water/ no HVAC. These mainstream customer categories in Heyfield were identified through detailed ecological surveys and analysis of data collected using Wattwatchers monitoring devices.

## 4.2 Key inputs and assumptions

Table 4 summarises the key assumptions used in this study for the tariffs, the cost of the battery asset and associated enablement technologies, as well as the general modelling assumptions.

The load profiles and costs have been assumed to remain steady through the project lifetime, and the modelling has not included the potential for load flexibility or energy efficiency.

We have modelled a 3 kW, 3.3 kWh battery for residential use in Heyfield. The reason for this choice was two-fold: First, this battery capacity is suitable for typical residential solar PV systems in Heyfield, which usually have been found to have a capacity of between 3 kW and 5 kW. This means that the battery size is sufficient to store the excess solar energy generated during the day and use it during the evening or at times when the solar panels are not generating enough power.

Second, the 3.3 kWh capacity is a good balance between cost and performance. It provides enough energy storage capacity to meet the needs of most residential customers, while also keeping the cost of the battery system relatively affordable.

Overall, the choice of a 3kW, 3.3 kWh battery for residential use is deemed a practical and cost-effective solution that can help homeowners maximise their use of solar energy and reduce their reliance on the grid.

The modelling assumptions used in this study are simplified to ensure practicality, while the level of detail in the analysis is deemed sufficient to derive meaningful insights for this stage of the community battery feasibility process.

*Table 4 Summary of key assumptions – battery in homes (behind the meter)*

| **Parameter** | **Value(s) used in modelling** | **Comment/ source** |
|---|---|---|
| Residential electricity tariff (including battery) | 0.4081 \$/kWh peak<br>0.1965 \$/kWh off-peak<br>0.1962 \$/kWh controlled<br>**Service charge:** \$1.2994/ day | Victorian Default Offer Rates[10] for AusNet Services area |
| Network tariff (including battery) | 0.2291 \$/kWh 3pm-9pm weekdays<br>0.0477 \$/kWh all other times<br>**Service charge:** \$125.07/ year | Enables calculation of stakeholder outcomes to include network business and retailer |
| Feed in tariff[i] | \$0.05/kWh | Minimum feed in tariff set by Essential Services Commission[11] |
| Battery type | Lithium ion | Currently the most available and cost-effective. |
| Battery capacity | 3 kW<br>3.3 kWh (2.9 kWh usable) | Discharge duration = 1 hour[12] |
| Expected lifetime | 10 years | Proven safety and 10 years warranty |
| Battery capital cost | \$1,500/kWh | Includes an additional inverter to manage the battery bank for a DC-coupled battery[13] |
| Capital cost of replacing battery cells | N/A | The battery doesn't reach its maximum throughput over 10 years, so no replacement costs are included |
| Battery O&M cost | N/A | No O&M cost is considered for household-level BTM batteries. |
| Battery round-trip efficiency | 90% | The ratio of the energy output to energy input during a full charge-discharge cycle. |
| FCAS market exposure | 100% | The battery can offer all available electricity capacity to provide FCAS (ancillary) services to the market, rather than just selling energy on the spot market. |
| FCAS revenue allocation | Customer's share of FCAS revenues = 50%<br>Retailer's share of FCAS revenues = 50% | The total FCAS revenues are shared equally between the retailer and customers. That is, it is assumed that the retailer acts as an aggregator and provides access to the FCAS market, with taking 50% of the revenues and passing the rest onto the end-consumers. |
| Time period of the original data used | One year from July 2021 to June 2022 with hourly resolution | Used the typical load and solar PV generation profiles derived in Milestone 5.1, *Typical residential load profiles for Heyfield*. |
| Project lifetime/ planning horizon | 10 years | January 2024 to December 2033 |
| Discount rate | 4% | The recommended discount rate for Commonwealth infrastructure projects[14] |

The methodology is as described in Section 2.3. Note that, in accordance with Figure 5, the customers pay the retail tariff for any imports under the net metering mechanism and receive FIT for their excess solar exports.

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[i] Note that the current premium FiT of \$0.60/kWh expires in 2023 or 2024 depending on the start date, and therefore, not considered in this study.

As described in the table above, it is assumed that FCAS revenues are shared equally between the retailer and the customer, with the retailer acting as a financially responsible market participant (FRMP) for providing access to the market through aggregation and giving smaller customers enough scale for participation.

Any arbitrage opportunities that arise from the use of the BTM batteries in arbitrage applications are assumed to be 100% for customers. This means that customers can potentially benefit from the price differences between buying and selling electricity.

In this setting, the retailer’s margin is calculated as the algebraic sum of retail charges (positive), network charges (negative), wholesale charges (negative), and 50% of FCAS revenues where applicable (positive). Also, the customers’ bills are calculated as the retail charges (positive), capital and O&M costs of the battery where applicable (positive), and 50% of FCAS revenues where applicable (positive).

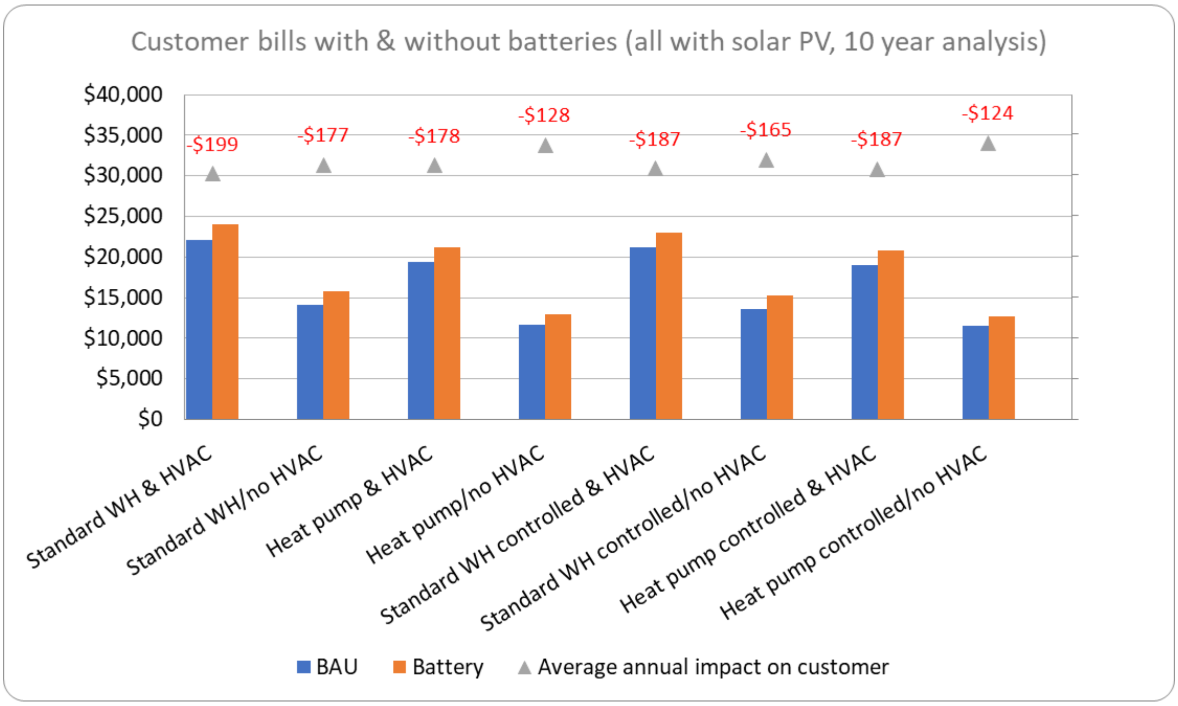
As discussed earlier, in BTM systems, the primary source of value for batteries is increased self-consumption of solar energy instead of grid arbitrage, as the value of self-consumed solar energy is typically greater than the FIT received for exporting excess solar energy to the grid. That is, there is limited potential for grid arbitrage in BTM settings as compared to FTM systems where the value of export is not limited to FIT. However, it should be noted that the employed software takes into account this revenue stream in the associated optimisation process.

## 4.3 Economic results for households

Figure 9 shows the customer bills for various customer categories with and without batteries – without any grants and with a 50% grant. The batteries are not economic without a grant and break even at about 50% grant ($2,250 per household).

The battery is slightly more cost-effective in the cases without HVAC, due to the opportunity to store more surplus solar for later use. This insight holds true when comparing the cases with day-rate standard and HP hot water systems as the cases with HP hot water are associated with lower consumption when solar is generating.

Another important insight is that connecting the hot water sub-load to the controlled load tariff reduces the customer bills for all the four relevant customer types studied compared to the corresponding cases without the controlled load tariff applied to the hot water sub-load.



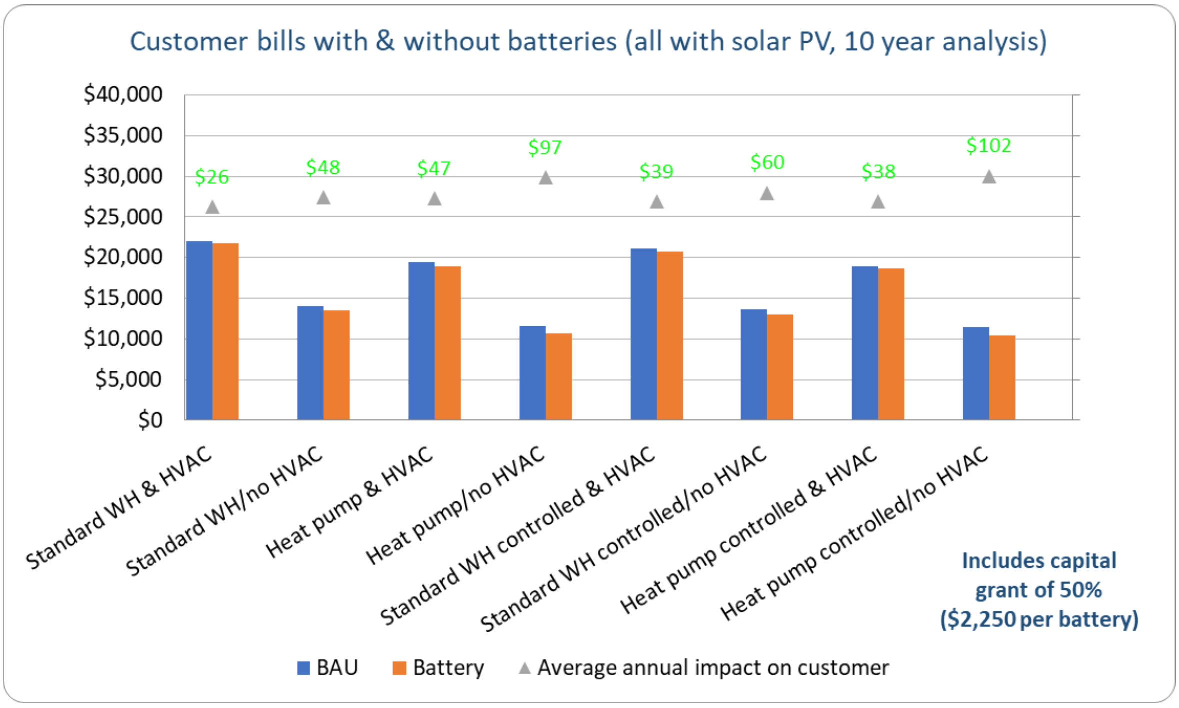


*Figure 9 BTM batteries in homes – impact on customer bills (1 hour energy storage)*

## 4.4 Conclusion – Residential BTM batteries

This analysis focused on the economic viability of deploying BTM batteries in residential households with solar PV systems. Our results suggest that households with TOU tariffs cannot benefit significantly from the deployment of BTM batteries without grant support. The battery is more cost-effective in cases without HVAC, where surplus solar can be stored for later use. We also found that the connection of the hot water sub-load to the controlled load tariff reduces customer bills for all customer types.

We found that a grant of 50% is needed for the battery to be close to cost neutral. Overall, the results provide valuable insights into the feasibility of deploying BTM batteries in residential households, with the potential to improve self-consumption and reduce reliance on the grid.

The results from this household-level case study are used in Section 6.2 for a direct comparison of the FTM battery scenarios with a fleet of BTM batteries with the same total energy capacity as the FTM battery.

## 5 Case study 3: Battery at the pub (behind-the-meter)

### 5.1 Overview

The third scenario we evaluated involves installing a BTM battery with varying energy capacities at a solar PV-equipped commercial premise, specifically a pub. The goal of this scenario was to assess the potential benefits of deploying a battery at a commercial premise with larger load and different patterns of energy consumption compared to domestic loads. By analysing the impact of the BTM battery on self-consumption, as well as participation in the FCAS market and taking advantage of grid arbitrage, we aimed to provide insights into the feasibility and economics of this type of deployment.

The stakeholders involved in the study include the network business, the retailer, the commercial customer (i.e., the pub), and the community as a whole as the owner of the shared battery asset. The analysis assumes that a third party will operate the battery on behalf of the community, allowing for a more efficient and cost-effective operation. The commercial premise evaluated in this scenario is currently on TOU pricing without demand charges.

The analysis involves evaluating a range of battery sizes from 2.5 kW/ 5 kWh to 50 kW/ 100 kWh. This range of battery sizes was chosen based on the excess solar energy generated at the pub and the associated underlying load patterns, and in part to see the impact of extreme scenarios. It is important to note that the analysis is based on actual consumption data, providing a realistic representation of the energy consumption patterns of the site of interest. This wide range of battery sizes allows us to understand the potential benefits and limitations of deploying BTM batteries in larger commercial premises with different energy consumption patterns and different tariffs compared to residential customers.

### 5.2 Key inputs and assumptions

Table 5 summarises the key assumptions used for the tariffs, the cost of the battery asset and associated enablement technologies, and the general modelling assumptions. The load profiles and costs have been assumed to remain steady through the project lifetime, and the modelling has not included the potential for load flexibility or energy efficiency.

We have modelled seven scenarios: (i) a base case without battery, (ii) a 2.5 kW/ 5 kWh battery, (iii) a 5 kW/ 10 kWh battery, (iv) a 7.5 kW/ 15 kWh battery, (v) a 10 kW/ 20 kWh battery, (vi) a 25 kW/ 50 kWh battery, and (vii) a 50 kW/ 100 kWh battery.

It is assumed that value is shared 70% to the battery operator/ community, and 30% to the pub.

The study employed some simplified modelling assumptions to ensure practicality while maintaining a sufficient level of analytical detail to obtain valuable insights for the community battery feasibility assessment.

The methodology is as described in Section 2.3. Note that, in accordance with Figure 6, the pub pays the retail tariff for any imports under the net metering mechanism and receives FIT for its excess solar exports. The value-sharing arrangement for the community-owned battery located at the pub has also been assumed as battery operator/ community 70%, pub 30%.

In this setting, the retailer's profit or loss is calculated as the algebraic sum of retail charges (positive), network charges (negative), and wholesale charges (negative). Also, the community's profit or loss is calculated as the difference between the total retail charges in the baseline case without battery and the associated battery-integrated case, plus the associated FCAS revenues, minus the battery capital and O&M costs.

*Table 5 Summary of key assumptions – battery at the pub (behind the meter)*

| Parameter | Value(s) used in modelling | Comment/ source |
|---|---|---|
| Commercial electricity tariff (including battery) | 0.3521 $/kWh peak<br>0.1817 $/kWh off-peak<br>Service charge: $1.2994/ day | Victorian Default Offer (AusNet Services area) for small commercial tariff[15]<br>This is very close to the current tariff at the pub. |
| Network tariff (including battery) | 0.1932 $/kWh 9am-9pm weekdays<br>0.0471 $/kWh all other times<br>Service charge $125.07/ year | Standard network tariff (small business time of use) in the AusNet area – NAST12[16] |
| Feed in tariff | $0.05/kWh | Minimum feed in tariff set by Essential Services Commission[17] |
| Battery type | Lithium ion | Currently the most available and cost-effective. |
| Battery capacity | 2.5 kW/ 5 kWh<br>5 kW/ 10 kWh<br>7.5 kW/ 15 kWh<br>10 kW/ 20 kWh<br>25 kW/ 50 kWh<br>50 kW/ 100 kWh | Discharge duration = 2 hours |
| Expected lifetime | 10 years | The battery health analysis suggests that the battery will not reach its maximum throughput over the expected lifetime. |
| Battery capital cost (initial) | $1,440/kWh to $1,590/kWh depending on the size (The larger the size of the battery, the lower its per unit cost) | Includes an additional inverter to manage the battery bank for a DC-coupled battery system[18]. Development costs have not been included. |
| Capital cost of replacing battery cells | N/A | Battery replacement isn't needed in that time as the batteries cycle less in the BTM situation. |
| Battery O&M cost | N/A | No O&M cost is considered for BTM batteries. |
| Battery round-trip efficiency | 90% | The ratio of the energy output from a battery compared to energy that input during a full charge-discharge cycle. |
| FCAS market exposure | 100% | The battery can offer all available electricity capacity to provide FCAS (ancillary) services to the market, rather than just selling energy on the spot market. |
| Value sharing arrangement | Battery operator/ community 70%<br>Pub 30% | |
| Time period of the original data used | One year from July 2021 to June 2022 with hourly resolution | Used the NMI data obtained from AusNet Services, which included net load and exports. The underlying load was estimated based on synthetic solar generation data calculated using a solar tool[19], as actual solar generation data was not readily available. |
| Project lifetime/ planning horizon | 10 years | January 2024 to December 2033 |
| Discount rate | 4% | The recommended discount rate for Commonwealth infrastructure projects[20] |

## 5.3 Economic results for stakeholders

Figure 10 shows the economic analysis by stakeholder for the BTM battery at the pub without any grants. The following insights can be drawn from the various battery scenarios:

- The smaller sizes of batteries are the most economic, with reduction in value as the battery size increases. Comparing the lowest and highest battery sizes, the net profit is reduced by almost $7,700 per year between the 5 kWh and 100 kWh scenarios.
- The capital expenditure (CAPEX) required to install a BTM battery at the pub can be substantial, with the larger systems costing significantly more. For example, the 100 kWh battery scenario requires a capital investment of $146,300, while the 5 kWh battery scenario only requires $7,800.

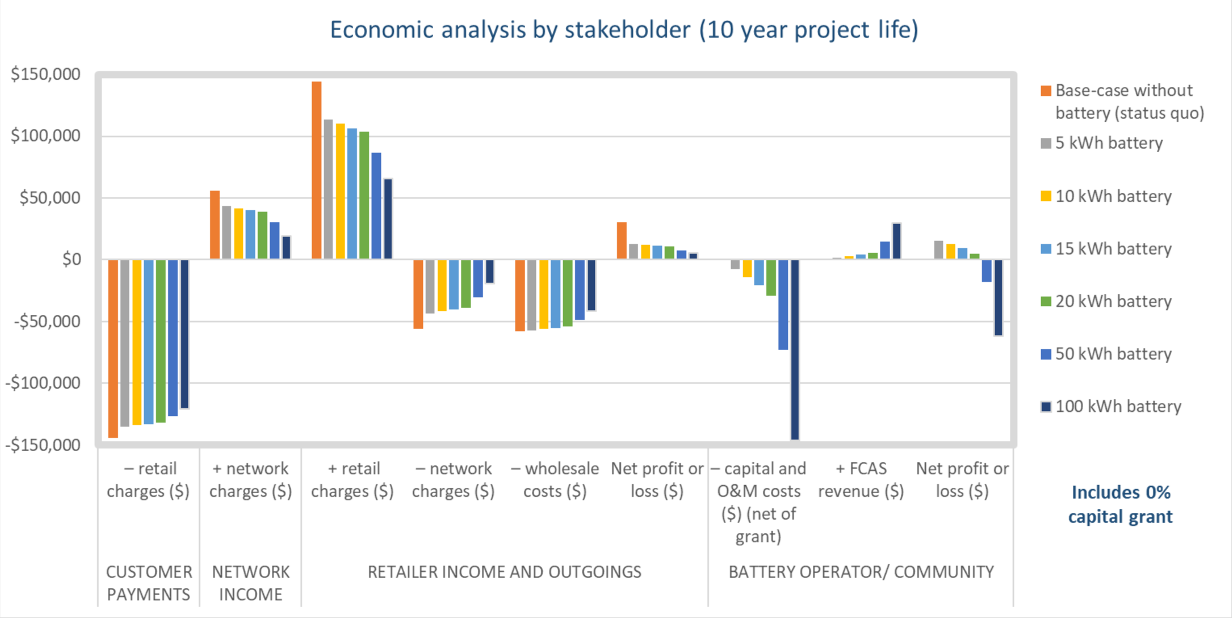


*Figure 10 BTM 100 kW/ 2 hour battery at the pub – without grant*

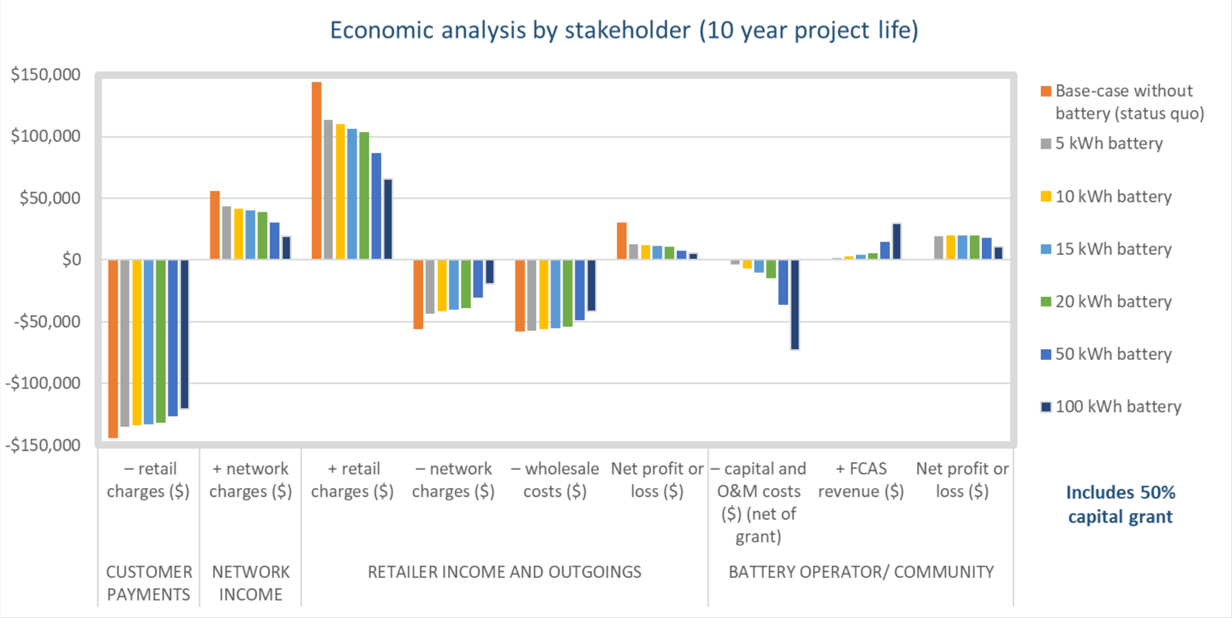


*Figure 11 BTM 100 kW/ 2 hour battery at the pub – with 50% grant*

Figure 11 shows the economic analysis by stakeholder for the BTM battery at the pub with a 50% grant. The economic viability results reveal several important insights, as follows:

- The addition of a BTM battery can provide a net profit for the community on an annual basis. The highest income is achieved with the 15 kWh battery size, providing $20,200 per year, while the lowest is achieved with the 100 kWh battery size, resulting in a net loss of $11,000 per year.

- The net profit for the pub slightly increases with the size of the BTM battery up to the 15 kWh battery size, beyond which it starts decreasing due to a combination of factors. Although larger BTM batteries can potentially generate additional revenue through improved self-consumption, as well as services such as FCAS and arbitrage, the corresponding increase in capital costs ultimately results in diminishing net profit beyond a certain battery size. This highlights the importance of carefully balancing the trade-offs between battery size and profitability in BTM batteries.

## 5.4 Conclusion – BTM battery at the pub

Based on the analysis conducted, it can be concluded that installing a BTM battery at a commercial premise, such as a pub, can be economically feasible under certain conditions. The range of battery sizes studied – which were mainly chosen based on the excess solar energy generated by the pub and the underlying load patterns – showed that undersized batteries are the most economic option without any grants (up to 10 kW/ 20 kWh). However, it is worth noting that small batteries behind-the-meter have less potential for energy resilience provisions. Therefore, the selection of battery size should consider the trade-off between cost and resiliency, with larger batteries providing more energy resilience but at a higher cost.

# 6 Discussion and conclusions

This study investigated the economic viability of deploying an FTM battery on a residential feeder, as well as residential BTM batteries and a BTM battery at a commercial premise, specifically a pub, in the town of Heyfield, Victoria. The analysis focused on various scenarios for each case, allowing for a comprehensive evaluation of the economic feasibility and potential benefits for stakeholders.

## 6.1 Overview of economic results

### *FTM battery on the residential feeder*

This case study examined the installation of an FTM battery on a residential feeder, including the role of trial network tariffs in supporting their deployment. The study assumes that customers are on time-of-use (TOU) pricing, and the business case for the battery is evaluated based on its ability to generate revenue through improved self-consumption, grid arbitrage and FCAS market revenues. The stakeholders involved in the study include the network business, the retailer, residential customers (both with and without solar), and the community as a whole – as the owner of the shared neighbourhood battery asset.

The five scenarios studied were no battery, a battery operating under standard network tariffs, and three different trial tariffs that other DNSPs have offered (currently there is no AusNet Services trail tariff, although one is in development).

The results for the FTM battery indicated that without any grants, deploying the battery in this context is not financially viable, as all the network tariffs investigated show significant losses. However, with a 95% grant of capital costs, the project shows a positive net profit for all scenarios, ranging from $1,200 to $8,700 per year, depending on the associated network tariff. The break-even point is estimated to be between a 75% and 95% grant. The battery operation surcharge ranges from 12% to 85% of the net profit, indicating the significant impact of battery operation arrangements on overall profitability. Overall, the deployment of an FTM battery in this context is economically feasible only with a high level of grant support.

### *BTM batteries on a residential feeder*

This case study examined the installation of BTM batteries at individual households with solar PV systems in Heyfield. The study analysed eight customer categories with unique load shapes, including standard resistive and heat pump hot water systems, with or without HVAC. The primary objective was to evaluate the impact of deploying a fleet of BTM batteries on electricity bill reduction and self-consumption improvement for individual customers, and to compare the economics of deployment with an FTM battery of the same overall capacity.

The study found that a 50% grant is necessary for the battery to be economically viable, with a break-even point of approximately $2,250 per household. Without any grants, the batteries are not economic, and households do not benefit economically from their deployment.

### *BTM battery at the pub*

The study evaluated the installation of a BTM battery at a solar PV-equipped commercial premise, specifically a pub, with varying energy capacities. The analysis involved evaluating a range of battery sizes from 2.5 kW/5 kWh to 50 kW/100 kWh, with the goal of assessing the potential benefits of deploying a battery at a commercial premise with larger load and different patterns of energy consumption compared to domestic loads. The analysis assumed that the community would own the battery, and share the benefit with the pub.

As shown in Figure 11, the economic analysis by stakeholder for the BTM battery at the pub without any grants and with a 50% grant showed that the smaller sizes of batteries are the most economic, with a reduction in value as the battery size increases.

In the case with a 50% grant, the addition of a BTM battery can provide a net profit for the community on an annual basis, with the highest net profit achieved with the 15 kWh battery size, providing $20,200 per year, while the lowest net profit is achieved with the 100 kWh battery size, resulting in a net loss of $11,000 per year.

In addition, the capital expenditure (CAPEX) required to install a BTM battery at the pub can be substantial, with the larger systems costing significantly more.

## 6.2 Comparison of FTM battery and fleet of BTM batteries on residential feeder

Figure 12 provides a comparison of the feasibility of installing a fleet of BTM batteries versus an FTM battery. The comparison assumes that each system has the same amount of storage capacity (200 kWh), and the same feeder is used for both cases. The FTM battery case is a 100 kW/2 hour battery installed on a residential feeder that serves 101 customers, 31 of whom have solar panels installed, while the BTM fleet of batteries assumes 60 customers with solar panels and 3.3 kWh batteries.

The installation of the BTM fleet would require a significant increase in the number of homes with solar panels, from the current 30% to about 60%, which would not be feasible without battery storage due to the limitations of the feeder's hosting capacity. It is important to note that the costs included in the comparison are for battery storage only, and do not include the costs associated with increasing the number of solar installations.

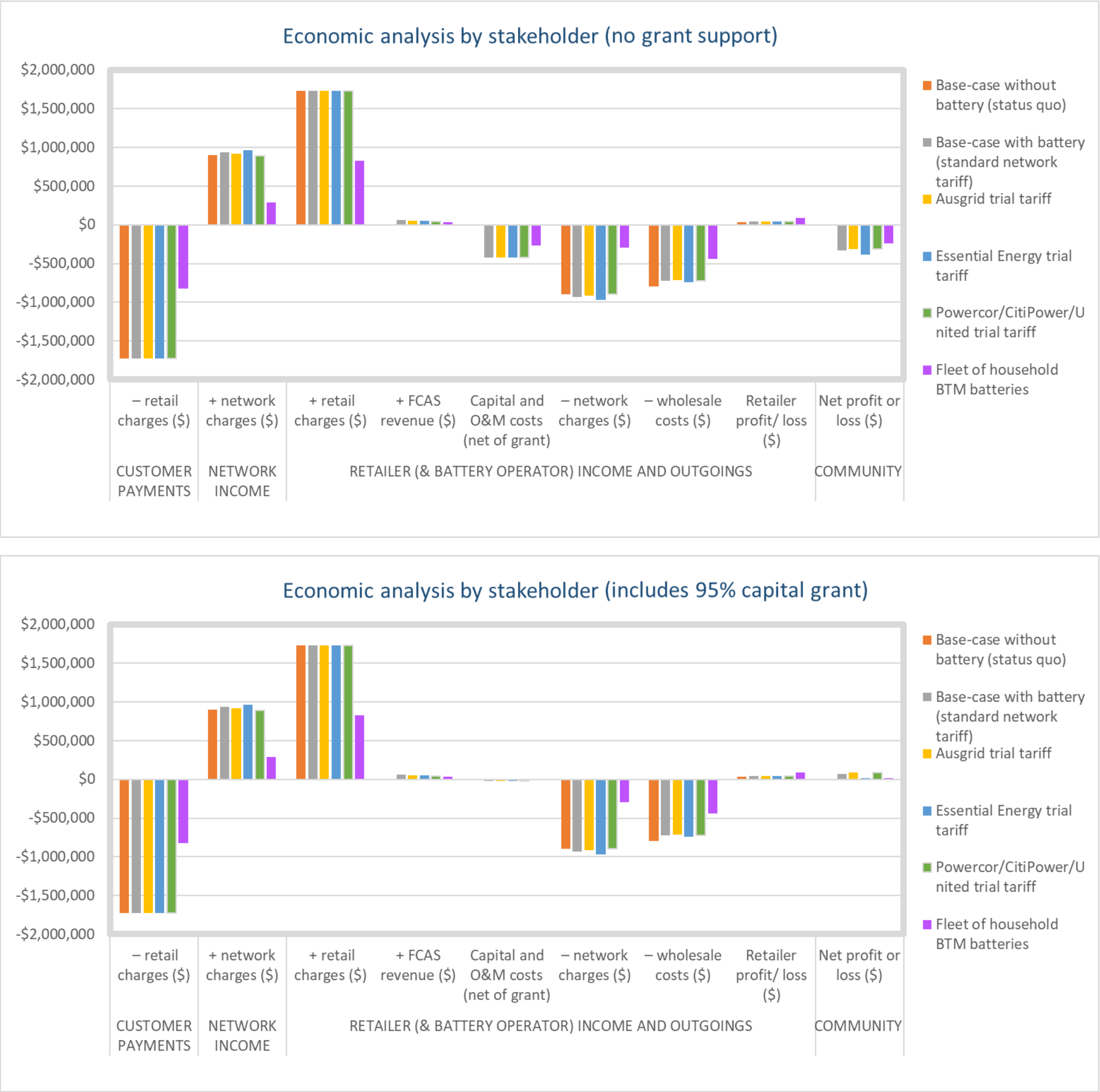


*Figure 12 Comparison of FTM battery with BTM fleet of batteries on the same feeder*

For the comparative analysis, after conducting a separate stakeholder analysis on the eight customer types (defined based on their hot water and space heating systems), we scaled up the BTM fleet by taking the average of the analysis results and multiplying by the number of solar customers with batteries (n = 60) that provides a total battery capacity of 200 kWh, equivalent to that of the FTM battery.

The results show that the BTM batteries require less grant support, with about 50% required to break even, compared to 75%-95% required for the FTM case. However, in the BTM case, the grant would be going to private individuals and may not bring the same community benefits as the FTM case. Thus, the decision to install either a fleet of BTM batteries or an FTM battery should be made based on multiple factors, including costs, community benefits, and technical factors.

## 6.3 Risks and caveats

While our economic modelling provides valuable insights into the potential benefits of the proposed project, it is important to acknowledge the inherent risk. Some of the risks that need to be taken into consideration are:

- *Availability of trial tariffs:* The economic analysis depends on having trial tariffs in place to support FTM batteries, but these tariffs may not be available. The trial tariffs modelled here are available in other distribution areas. As of now, AusNet Services does not offer a community battery trial tariff, and any tariff it does offer could result in better or worse outcomes, and will certainly affect the economics of the project.

- *Stranded assets:* After five years, the storage cells will need to be replaced in the case of the FTM battery. The cost of cell replacement may be lower or higher than modelled at the beginning of year six, and contractual arrangements in the beginning should determine who takes this risk if it is decided to go ahead with the project.

- *Variability of retailer's throughput charge:* The analysis depends on variables such as the retailer's throughput charge, and these may differ from the values uses, and may vary over the course of the project. Any changes over the project lifetime would affect the economics of the project.

- *Speculative costs of software and control technologies:* The analysis includes speculative costs for software and control technologies. If the actual costs are different from the modelled costs, it could affect the overall economics of the project.

There are also a number of caveats that should be considered. These include the limitations of the modelling software, modelling assumptions and data used, the uncertainties associated with future time series data forecasts (load, local generation, and prices), and the specific characteristics of the sites and customers considered in the analysis. Some of the factors which may mean that real outcomes differ from predicted are:

- Perfect foresight: The software we have utilised assumes so-called perfect foresight on time-series data. That is, it anticipates future loads, generation, and prices, in order to gain the best value possible from the battery, but this may not be realistic in the real world. In other words, we have assumed the use of dynamic/ adaptive control of the charging/ discharging of batteries to achieve the best-case results. This may not be feasible or practical, and the actual savings may be lower if these assumptions are not met.

- Spot market costs: The modelling software uses wholesale price profiles to estimate energy costs, although in reality, retailers will have complex arrangements in place to purchase electricity, with only a small portion sourced on the wholesale market.

- Wholesale market volatility: The results of this study are based on a representative year with particularly high wholesale prices because of high gas prices. This implies that the revenue streams generated by the battery systems may not be as high in years with potentially lower wholesale prices, and hence the results of this study should be interpreted with caution when considering future market conditions.

- Parameter settings: The performance of the battery systems may vary depending on the specific parameter settings used in the model. The discount rate and battery parameter settings used in this study are based on assumptions and values that may not perfectly reflect real-world conditions in the future, and therefore, actual results may differ from those presented in this study.

- Limited scenarios: Additionally, this study has focused on a limited number of scenarios and did not account for all possible factors that may impact the economic viability of battery storage systems. Therefore, the results should be interpreted with caution and should only be considered as indicative results.

## 6.4 Recommendations

Based on the analyses and findings presented, none of the batteries is economic without subsidy, with the potential exception of small batteries (10kW/ 20kWh) behind the meter at commercial premises.

The most economic case is undersized batteries at the pub, followed by the BTM fleet on the residential feeder, followed by the FTM neighbourhood battery on the residential feeder. The first two cases are likely to require grants of 50% and upwards, while the neighbourhood battery is likely to need grants 80% and upward in order to give a return to the community and/or the customers.

As none of the cases is likely to be economically compelling without a grant, the optimum case depends primarily on community objectives. Battery operation is determined partially by the aspirations of the project and business model, so firmer definition of these objectives is needed to determine the optimum battery size and operating mode prior to undertaking the business case. It might be useful for Heyfield to trial all three battery types, at least to a more detailed business case, as different applications achieve different aims. In all cases where the battery is a shared community asset, it is likely that fixed costs (including administrative set up costs) are significant, so sharing these costs among a fleet of batteries is advised.

The following steps are recommended to create an energy storage pathway for Heyfield:

1. Identify wider project objectives to use as assessment criteria for different battery cases. Objectives could include, for example, increasing hosting capacity to reach 100% RE, enabling load growth, enabling fast EV chargers.

2. Undertake detailed business cases for:

    - A fleet of commercial BTM batteries (potential size 20-50 kWh)

    - A 50 kW/100 kWh FTM neighbourhood battery

    - A fleet of subsidised BTM residential batteries to go to existing solar homes/ to homes installing solar

3. Evaluate the impact of the expiration of premium feed-in tariffs[j] on solar customers, which could lead to increased electricity bills for solar customers. Implementing community batteries, supported by grants, could be one of the effective ways for the community to mitigate the bill increase by maximising the use of their own generated electricity.

4. Provide education and training to households to help them understand the benefits of energy storage systems, and how to use them effectively.

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[j] As of November 2024, the premium feed-in tariff rate will expire and be reduced from $0.60/kWh to $0.05/kWh. This will increase electricity bills for solar customers and make it much less financially beneficial to export electricity to the grid.

5. Encourage the use of energy monitoring and management systems, such as Wattwatchers monitoring devices, which can track energy production and consumption, allowing homeowners to make informed decisions about their energy usage in relation to the state of charge of the battery.

In addition, based on the analysis presented for the commercial premise of interest, a strategy for implementing BTM battery systems in residential and commercial settings may involve starting with a relatively small battery coupled with an appropriately sized solar array to maximise the cost-effectiveness of the system, while developing the institutional arrangements to manage community energy projects and providing a degree of resilience. As energy demands increase, the system sizes could be gradually increased for both the solar array and the battery storage to provide greater energy independence and resilience, while balancing economic considerations. This approach could help ensure that the system meets the site’s energy needs and resilience requirements, while maximising cost-effectiveness. However, the most effective pathway depends to a large extent on community aspirations for the project and for energy in general.

# Appendix A Inputs and assumptions for battery costs

There is limited experience in Australia at this stage for suitable capital costs for a community scale battery. The various feasibility reports that have been completed under Victoria's Neighbourhood Battery Initiative quote widely varying costs, with different inclusions and often emphasise a 20% to 30% uncertainty factor. For example, $1,000/kWh is the low end of the range where cases minimise installation and project design costs, $4,900/kWh has been quoted for the most expensive battery in the Philip Island assessment.

Reliable market information is split across two scales – utility batteries in the 10MW to 100MW scale and household batteries in the 3kW to 20kW range. At the scale and low voltage application, this study could consider batteries in the range 50kW to 500kW. The following four relevant applications of community scale batteries incorporate high "learning" costs when considering how the money in each case was spent and therefore only provide modest indications about the cost of a community-scale battery:

- Yarra Energy Foundation, $800,000 grant. Ongoing support from YEF, over 1 year in project development work. Size: 120kW and almost 3 hrs storage at full load (309kWh)[21]

- Tarneit, approximately $1m. Powercorp identified approximately 75% as "learning costs" which could reduce dramatically in future iterations[22]

- Ausgrid, Beacon Hill. Supported by ARENA. Predicting around $400,000 in future. Size: 150kW and almost 2 hrs storage at full load (267kWh)[23]

- Western Power. PowerBank 3 will use 116kW/464kWh batteries. PowerBank 1 received $3.3m from ARENA and was the first project of this kind in Australia. Public information about current costs is limited. PowerBank 3 will be 9 batteries so Western Power is beginning to develop a repeatable project approach with a fixed business model[24].

Projected future costs, economies of scale and breakdown of costs were considered to choose an appropriate capital cost for the modelling in this report.

### Projected future costs and costing calculations

The two main drivers of battery size are capacity usually provided as kW and length of time or volume of energy that defines the battery operation, usually provided as kWh or hours duration.

Capacity (kW) x Hours Duration = Size (kWh).

Some components of a battery system are priced according to capacity, especially the inverter, switchgear and protection equipment. The battery cells are the key to energy production and are priced according to size in kWh.

CSIRO track annual costs of batteries and full battery systems for utility scale applications and in reporting to the Australian Energy Market Operator for its energy system planning. Figure 13 shows the projected cost of large battery systems according to the CSIRO (BoP means Balance of Plant and refers to the inverter, containerisation and other connection and control systems).

This graph can be interpreted as demonstrating a cost equation of:

*Capital Cost = $550 x Capacity (kW) + $300 x Duration (kWh)*

By 2035, the main cost reduction is expected to come in the Lithium ion cells that are projected to reduce costs to $100 x duration (kWh) with minimal movement on the costs of Balance of Plant.

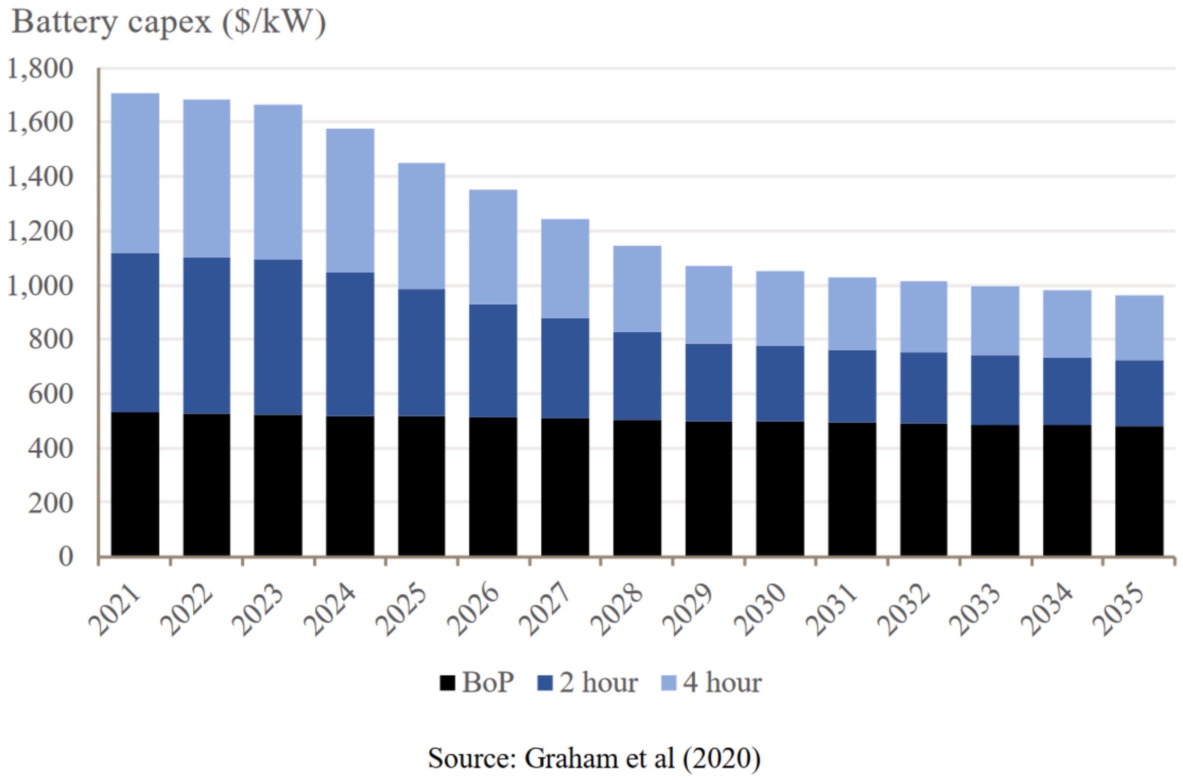

*Figure 13 Projected Capital Costs for grid scale batteries (CSIRO)[25].*

Enea took a similar approach with its report[26] for Macedon Ranges and concluded a cost equation of:

*Capital Cost = $335 x Capacity (kW) + $575 x Duration (kWh) + $205,500* for community-scale battery projects.

Our assessment of a range of battery projects around the size of 100kW/ 200kWh suggests the capital cost of the core battery system should aim toward $1,000/kWh when installing a 2 hour battery. We have used the following cost equation for testing different battery sizes and durations:

*Capital Cost = $810 x Capacity (kW) + $620 x Duration (kWh) + $100,000*

A final reference point is household scale battery systems. The Solar Choice Battery Index[k] indicates a benchmark price of $1,500/kWh installed. This index includes rebates where available. One of the key benefits at the household scale is the ease of connection because a household is already connected to the grid and utilises its existing switchboard. This gives household system cost a head start over community-scale systems. It is also worth noting that the inverters for islanding or stand-alone capability, typically cost an additional $1,000, adding around 10% to the cost of a household system.

### Breakdown of costs

The main cost components across different projects can be categorised into three areas with different cost drivers, plus ongoing operating costs.

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[k] https://www.solarchoice.net.au/residential/battery-storage-price/

**Fixed project costs**

Fixed costs are the most variable and site-specific component of a battery project. If a battery remains on the chosen site for a long time, these costs are unlikely to be repeated, even while other components wear out and need replacement. In an uncertain and innovative environment, these costs make projects uncompetitive and are written off as learning, capacity or long-term infrastructure investments. Nevertheless, they are real and projects that underestimate them will carry higher risks into the implementation phase of a project. The opportunity to carry out a full business case on battery projects will allow the Heyfield community to reduce these risks by delivering some of the components below in advance of implementation, and by pricing the remainder to a much higher degree of certainty.

- *Site-specific costs:* Ground preparation, electricity connection, possible grid extension, possible land purchase, site security.

- *Permissions and approvals:* Electrical connection approvals from the electricity network provider (i.e. AusNet Services) and planning approvals from council. This can also include legal costs and contractual costs relating to land and site owners and battery hosts.

- *Engineering and design:* Yarra Energy Foundation emphasised the importance of using a modular, factory-built system and opted for PiXii whose original role was systems for telecommunications assets and whose core technology is micro-inverters (i.e. can use cells from a range of manufacturers). When installing a modular system, much engineering and design is incorporated by the manufacturer and only additional integration engineering is required. The FTM battery project for Heyfield will need to invest in additional engineering during the business case to identify acceptable trade-offs between battery chemistry and community ambitions and to work with AusNet Services on the options for islandability.

- *Community engagement and stakeholder management:* The ambition needs to be to develop business model or models that can work for the householders that may be connected directly to the battery feeder or may be part of the wider community. Engagement will be an important component of both business case development and implementation because some agreements and social licence will need to be in place before the community agrees to proceed and apply battery funding.

- *Project development costs:* Invariably conceiving of a project, bringing all the components together, and managing stakeholders and governance involves a continuous organising presence. Project development can be a significant cost to any project, especially when it is the first of its kind, or involves significant customisation.

- *Other costs:* Some projects have allowed larger costs for metering and controls in order to participate in FCAS markets. At least one project has allowed for financial auditing.

A sample budget breakdown of $100,000 for fixed costs is shown in Table 6.

*Table 6 Sample budget of fixed costs*

| **Fixed cost element** | **Cost per project** |
|---|---|
| Ground preparation | $5,000 |
| Connection application and assessment | $15,000 |
| Permissions and approvals – council | $3,000 |
| Project development | $15,000 |
| Engineering and design | $25,000 |
| Community engagement | $22,000 |
| Other expenses such as metering and controls | $10,000 |
| Auditing | $5,000 |

It is evident from the sample budget that some expenses will carry significant uncertainty until additional work has been carried out in developing the business case and ascertaining project viability before defining more precisely the additional work that will be carried out during implementation – for example, engineering design and community engagement.

It is also clear that “cookie cutter” projects eliminate or streamline many of these costs and even approval processes can become cheaper over time as each relevant institution “learns”.

### Capacity- and energy-related costs

Capacity-related costs will include the inverter/s, the switchgear and protection, as well as the container to house the battery system. It will also include control systems, metering and monitoring and connection to the grid. It is evident that these capacity-related costs do not scale perfectly with battery capacity and there will be some economies of scale for larger projects. As discussed above, this report uses $810 for every kW of battery capacity to cover the costs of these components.

Energy-related costs mainly relate to the battery cells. Lithium ion batteries are part of a commodified market serving everything from mobile phones to electric vehicles and cells tend to come built into modular units that can be switched in and out of a battery system. Other battery chemistries will not obey the cost benchmarks that the industry, this report and many other neighbourhood battery feasibility studies have been using, so Lithium ion becomes the benchmark cost for assessment. This report uses $620 for every kWh to cover the cost of cells, their modular units, the associated cabling and unit-based monitoring and controls, as well as commissioning and testing costs. Table 7 compares the project cost for various combinations of battery capacity and discharge duration.

*Table 7 Core technology cost benchmarks for a range of battery system sizes*

| **Battery duration/ energy size** | **Cost per project** | | | |
|---|---|---|---|---|
| ***Battery capacity*** | ***1 hr*** | ***2 hr*** | ***4 hr*** | ***8 hr*** |
| 50kW | $71,770 | $102,840 | $164,980 | $289,260 |
| 80kW | $114,832 | $164,544 | $263,968 | $462,816 |
| 100kW | $143,540 | $205,680 | $329,960 | $578,520 |
| 120kW | $172,248 | $246,816 | $395,952 | $694,224 |
| 150kW | $215,310 | $308,520 | $494,940 | $867,780 |
| 200kW | $287,080 | $411,360 | $659,920 | $1,157,040 |
| 300kW | $430,620 | $617,040 | $989,880 | $1,735,560 |

### Operating costs

Operating costs can be minimal if the battery is set with a simple operating cycle and can be monitored remotely and fixed easily. Some projects, however, build in significant operating costs because there are licence fees for control software, high-speed electricity market access, data management and billing. A community battery indicates a level of community interaction and any benefit sharing may involve levels of communication and management that more technical projects consider irrelevant.

Operation and maintenance costs from $1,000 per year up to $14,000 per year can be found in other studies. Our assessment allows for $3,000 per year in operating costs.

### Economies of scale

KPMG, in its report for Ausgrid[27], provided a range from $3,500/kWh for smaller, short-duration batteries (e.g. 100kW/ 100kWh) down to $1,000/kWh for a larger 550kWh battery. The report was prepared in 2020, however it is a reminder to ensure that battery costs for smaller battery systems are not overly optimistic.

# Appendix B Additional modelling results – system dynamics

This appendix explains the dynamics that are taking place within the system in the case of the 100kW/ 200 kWh FTM battery on the residential feeder.

As discussed, the developed model is able to decide whether to sell any excess PV generation to neighbours (improved self-consumption), sell it back to the grid, store it in the battery for later onsite use (improved self-consumption), or for later more remunerative exports, or a combination of the above operational schedules at each time-step of the system operation.

In addition, the model is aware of the physical constraints of charging and discharging the battery and can import energy at low prices for later onsite use or later exports (i.e. grid arbitrage). It optimises the system to produce the best results based on all possible combinations of the above operational modes, taking into account all possible revenue streams.

It is important to note that the optimal trade-off results will vary depending on the network tariff the battery is connected to. In other words, the model will make different decisions based on the overall cost and availability of energy from the grid.

Overall, the model is designed to maximise the revenue from the battery system by taking into account all available options and constraints. However, it is important to note that the study assumes perfect foresight, which may not occur in real life scenarios. In practice, accurate forecasting software and programs may be required to achieve the same level of cost-effectiveness that is estimated in this study for the neighbourhood batteries of interest.

In this context, Figure 14 shows the system dynamics for a summer and winter week for the FTM battery case attached to the standard network tariff (i.e. NAST12). The system dynamics example provided shows a graph with a purple line representing the SOC profile. The SOC profile represents the state of charge of a battery over time. The graph also shows the slope of the SOC profile, which indicates the rate at which the battery is charging or discharging.

When the slope of the SOC profile is positive, it means that the battery is charging, and when it is negative, it means that the battery is discharging. The moments when the slope changes from positive to negative or negative to positive indicate when the battery starts to charge or discharge.

Furthermore, the steeper the slope of the SOC profile, the faster the battery is charging or discharging. Therefore, by looking at the SOC profile's slope, you can determine when the battery begins to charge or discharge and how fast it is charging or discharging.

Accordingly, the figure illustrates the battery's charge and discharge cycles over the week with respect to current and upcoming net load[l], with each cycle starting with the battery charging in the morning when the load is light and there is surplus solar energy. The battery then discharges in the afternoon and evening when the load is high, which is when it is most profitable to sell energy back to the grid and/ or use the stored energy onsite.

The analysis of the results highlights the importance of optimising the battery's charge and discharge cycles to maximise revenue and simultaneously taking into account the available solar energy, the demand for energy from the grid, and the network tariff to make the best decisions about when to charge and discharge the battery.

Making adjustments to the operation of a battery system based on the available options and constraints requires a high level of knowledge and foresight into the dynamics of the energy system. This includes understanding upcoming load demands, electricity prices, and the amount of onsite generation available.

To optimally schedule the charging/discharging of the battery with reference to the day-ahead, local generation, load demand, and wholesale electricity prices, the software package assumes that the 24 hours'

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[l] Net load is the actual amount of electricity demand from the power grid after subtracting the amount of electricity generated by on-site sources, such as rooftop solar panels. Here, the net load refers to the one before the battery, and not the one shown in the figure, which pertains to the net load of the battery-integrated system.

worth of wholesale prices, local generation, and demand for the coming day are available with zero uncertainty.

It is important to note that achieving perfect foresight is not always possible in real-life scenarios, as there are many unpredictable factors that can influence the behaviour of the energy system. Accurate forecasting software and programs may be required to achieve the same level of cost-effectiveness estimated by software packages that assume perfect foresight and optimise over multiple time steps at the same time. Therefore, while the developed model can make optimal decisions based on perfect foresight, it is important to acknowledge that this level of precision may not always be achievable in practice.

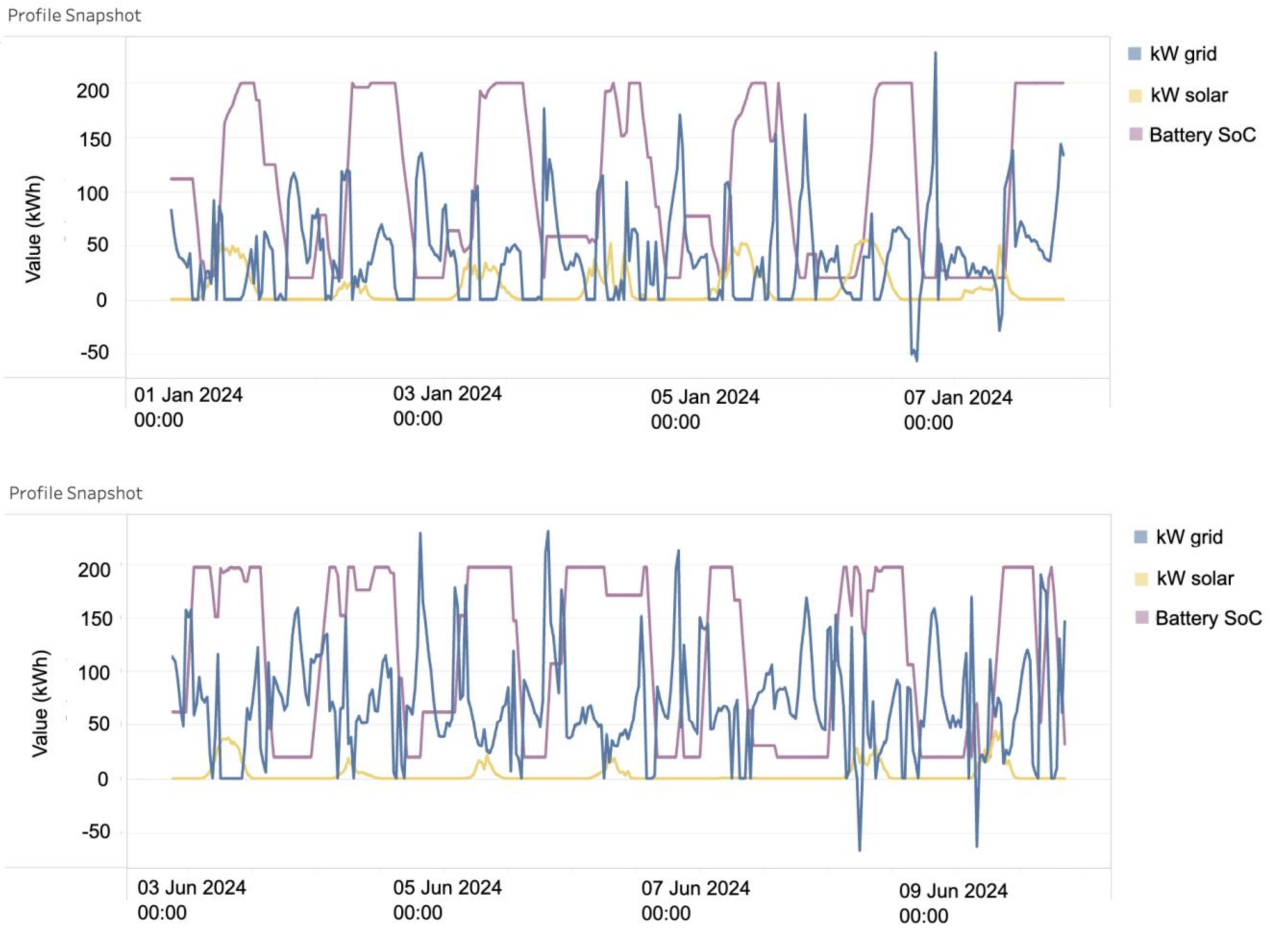

*Figure 14 Illustrative system dynamics for a summer and winter week.*

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