Modelled financial outcomes for community-scale batteries

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Introduction

The uptake of renewable energy in Australia is steadily increasing; to the point where it provided 32.5% of electricity over 2021 (Clean Energy Council, 2022). A significant amount of renewable electricity is being provided by distributed solar PV, which can have impacts on the distribution network such as voltage rise and reverse power flow, and system-level impacts including very low minimum demand and low levels of spinning reserve required for frequency control. These impacts are contributing to the need for increased uptake of batteries at the transmission and distribution levels. Batteries connected to the distribution network range from behind-the-meter batteries installed by customers through to larger in-front-of-meter batteries that may be installed by distribution network service providers (DNSPs) or third parties including retailers. Although these larger batteries are sometimes called community batteries, the term 'community-scale' batteries is often more appropriate because they may not be owned nor controlled by the community.

Interest from community groups in the development of community-scale batteries is increasing. In the 2022 Australian federal election campaign, the Australian Labor Party pledged to develop a program to provide $500,000 to each of 400 community batteries (Albanese, 2022). A key driver for community groups is the desire to export their PV electricity to the community-scale battery and then use it in the evening, which is reflected in the models offered by utilities – for example Endeavour Energy (2022) and Western Power (2022). However, as discussed below, a community-scale battery operating only in this way is unlikely to be financially viable. Fortunately, such batteries can also generate income by participating in the wholesale spot market, the frequency control ancillary services markets (FCAS), and by providing network support to the DNSP.

This paper reports on the development of a community-scale battery model for calculating the financial outcomes for the different stakeholders: (network companies, the retailer and local participants), where the battery may be owned by the DNSP, a retailer or a third party such as a community group. The results reported here are for a modelled community-scale battery located in north-west NSW and owned by a third party that can participate in all the markets outlined above.

Method

The optimisation model for the battery was developed in-house using python. It was formulated as a mixed integer linear programming problem. The model is iteratively fed half-hourly customer net load, large-scale solar generation, spot price and FCAS price data and, within the assigned parameters, solves for the maximum battery revenue one month at a time. The battery has a choice of bidding into the spot market, buying/selling from/to local households/businesses (through a retailer, and hereafter referred to as participants) and bidding into the six contingency FCAS markets. Additional revenue can be generated by discharging during pre-set peak demand events as a form of network support. It can also value-stack by participating in multiple revenue streams at the same time.

The results presented here were simulated using historical solar, load and price traces for 2021. The participant solar and load traces were provided by Solar Analytics, while the large-scale solar was sourced from AEMO's 2019 ISP database. The network tariff was based on the Essential Energy Bi-directional Distribution Support Tariff and the retail tariffs were based on Essential Energy's 2022/23 Pricing Proposal, with some modifications to promote consumption of energy during the day and export during the evening peak times. The Bi-directional Distribution Support

Tariff creates a de facto reward for providing network support and so no separate network support payment was included in this analysis. Solar, load, price traces and tariffs will of course be different in the future. The model had perfect foresight of demand, generation, and pricing within each iteration and therefore, the results presented in this paper can be treated as the upper end of potential revenue. This is something that will be adjusted in future research by including forecast uncertainties. Contingency events are rare and require small amounts of electricity compared to the capacity of the battery. Therefore, it was assumed that, although the battery was enabled for FCAS (and so still receiving FCAS revenue for being available), no electricity was used by the battery to deliver FCAS services (Bayborodina et al., 2021). A cycling penalty in $/kWh throughput was used to minimise the degradation of the battery. This approach is over-simplified and does not take into account the varying degradation rates at different DoD but is sufficient for reducing the number of cycles completed by the battery within each day. Default values for a few key parameters are shown in Table 1. At 5MW, this is larger than the community-scale batteries currently built and would most likely be connected directly to a zone substation.

Table 1 Default values used in the battery model

Parameter	Value
Battery capacity (MW)	5
Storage duration (hours)	2
Minimum SoC	10%
Round trip efficiency	90%
Cycling penalty ($/MWh)	40

Results

Amongst the large number of model outputs, three of the most interesting are: i) the impact of combining behind-the-meter (BTM) solar with the community-scale battery, ii) the impact of forcing a community-scale battery to use local solar or just encouraging this through the use of a spot price threshold, and iii) the degree of overlap between operating a community-scale battery to provide benefits to the local community versus simply maximising revenue by participating in spot and FCAS markets.

Combining large-scale solar with the battery

In some cases, the owner of the community-scale battery may wish to co-locate it with a behind-the-meter solar farm to allow for cheaper battery charging without paying use of system charges. This was modelled by assuming that the energy generated from the solar farm is free for the battery since they have the same owner. This represents an opportunity cost where solar is no longer sold into the spot market. Figure 1 illustrates the annual revenue generated by a combined battery and solar system with different capacity ratios to total 5MW (above which network connection costs increase significantly). Here, daily charge, demand charges and network payments are the components of the network tariff, energy arbitrage is the net revenue from buying from and selling to the spot market, local energy trading is the net revenue from buying from and selling to

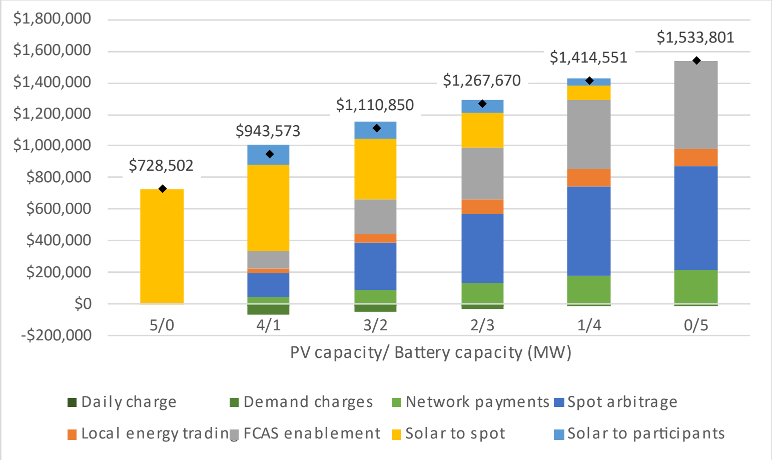

Figure 1. Annual revenue of a community-scale battery with behind-the-meter solar farm at various ratios based on one year of operation

participants, FCAS enablement is the revenue from participating in the six contingency markets, and solar to grid/ participants is the revenue of the BTM solar farm selling excess generation to the spot market/ community participants. For the current model, the battery-only system has the highest revenue and shortest simple payback time. Though adding a BTM solar farm allows the battery to charge for free during sunlight hours, because of the 5MW total battery and solar farm limit, this decreases the battery capacity available for FCAS and hence causes an overall decrease in annual revenue. Note that in this analysis the solar to grid revenue is based on spot prices, however a solar farm of this size could also sign a power purchase agreement (PPA). The equivalent PPA price for the electricity generated here on the spot market is $51.17/MWh.

The battery revenue is so high because it is based on a perfect foresight model and so these figures represent the maximum value for annual battery revenue.

Charging from local distributed solar versus the spot market

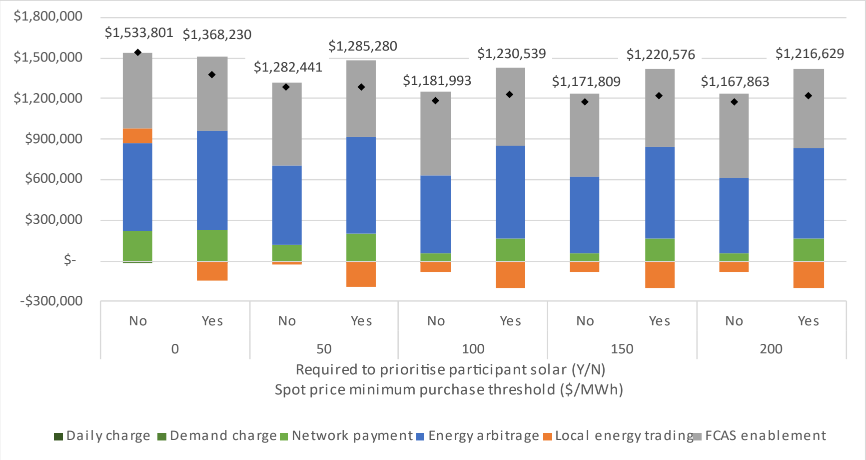

Figure 2. Annual revenue of a community-scale battery, forced to charge from local solar or not, at varying spot price minimum purchase thresholds

Depending on the tariffs applied to the battery, it may be more cost-efficient for the battery to charge from the spot market rather than buying solar exported from local participants via a retailer. With a focus on a community benefit model however, the owner may want the battery to prioritise charging from local solar. Figure 2 illustrates the impact on each of the revenue streams of forcing "local solar purchase" and also of using a price threshold such that the battery can't buy from the spot market unless the spot price is greater than this price threshold. In this scenario, the BTM solar farm was omitted to focus on the local solar. It was found that requiring the battery to purchase the participant solar in preference to the wholesale market decreases overall battery revenue because the spot price is often lower than the battery retail tariff. As a result of the forced local solar purchase, the battery often buys from the participants then sells to the spot market. Although this increases the income from energy arbitrage, it results in a greater decrease in income from local energy trading. The spot price minimum purchase threshold is another way of encouraging the battery to purchase electricity from the participants rather than the spot market. However, this method reduces income from energy arbitrage and network payments and makes local energy trading a net negative. It also reduces the number of cycles completed by the battery since the charge/ discharge cycles are more expensive.

Degree of overlap between community needs and battery needs

As highlighted above, although the community may want a community-scale battery to absorb their exported solar and provide it back in the evenings, the operator of the battery may need to participate in spot and FCAS markets to be financially viable. Figure 3 explores the overlap between these activities across a range of local-solar penetration rates (where overlap means they occur at the same time): 'Participant exports to battery' is the percentage that local solar exports overlap with battery charging; 'Battery imports from participants' is the percentage that battery charging overlaps with exports from participants; 'Battery exports to participants' is the percentage that battery discharging overlaps with participants drawing electricity from the grid; and 'Participant imports from battery' is the percentage that participants' use of grid electricity overlaps with battery discharging. The key points are that:

- Only a small proportion of participant exports overlap with battery charging – unless the battery is forced to charge from participants, and this declines as more participants have solar because the exports exceed the battery capacity
- More of the battery charging overlaps with participant exports as uptake of solar increases and is greater where the battery is forced to charge from participants.
- Generally, a large proportion of the battery electricity discharge overlaps with participant electricity use. This decreases slightly at higher solar uptake as participants use less grid electricity.
- Only a small proportion of the participants' electricity use overlaps with battery discharge because participants use electricity over a 24-hour period and battery discharge occurs at limited times of the day. However, when this assessment is limited to the times when the battery is discharging, the overlap increases to over 80%.

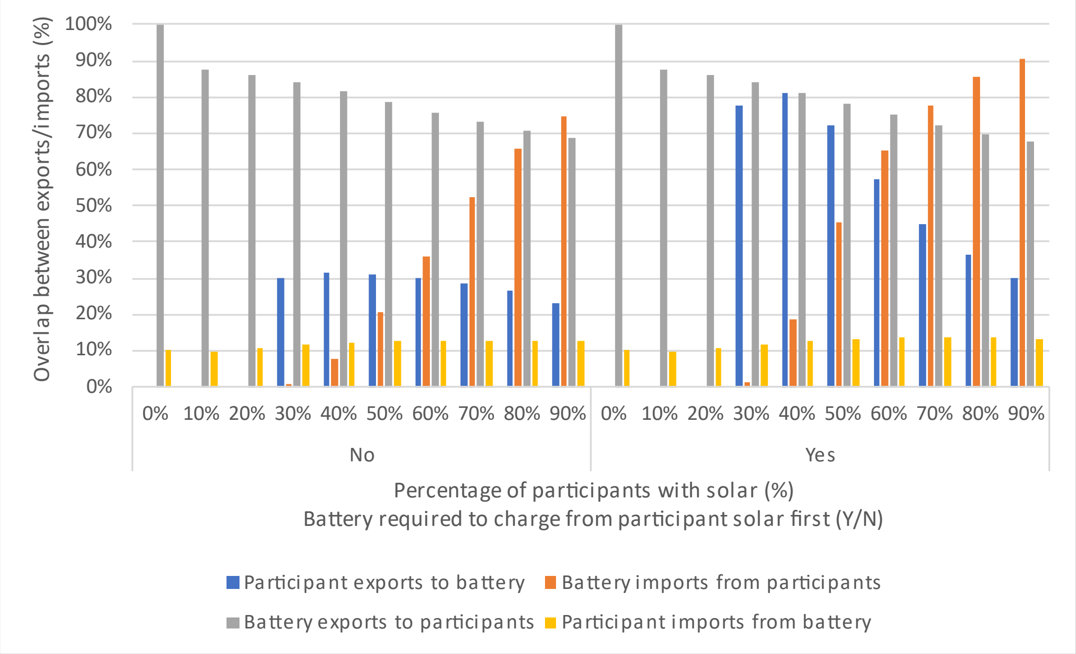

Figure 3. Overlap between battery operation and participant needs for a community-scale battery, forced to charge from local solar or not, at varying participant solar uptake

Conclusions

The financial outcomes for the various stakeholders in a community-scale battery depend on not only the size of the battery, but on many other factors including incorporation with a large-scale solar farm, the extent that is it charged from local participant solar and how this is achieved, the number of participants and the percentage that have solar, the tariffs that are applied, the various markets that it operates in, the revenue available from these markets and how the battery is operated. Participation in spot and FCAS markets can each make significant financial contributions, but these are generally lower if the battery is forced to charge from local participants.

If a community-scale battery is operated to maximise revenue, a large proportion of the battery exports could be said to be used by the participants, but generally less than 40% of the participant exports correlate with the battery charging. Due to the network tariff used in this study, a reasonable amount of the battery charge comes from participant exports, and although very little of the participants total electricity could be said to be provided by the battery, the correspondence is much higher at the times of discharge.

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