Battery Storage and Grid Integration Program

An initiative of The Australian National University

Policy Report: How trial network tariffs impact the potential benefits of Neighbourhood Batteries

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Executive summary

Neighbourhood batteries[1] strike a balance between individual household and grid-scale batteries, with capacities of 0.1-5 MW. These batteries are typically located on the distribution network to provide shared storage for households, businesses and to potentially increase network capacity to integrate more customer energy resources including rooftop solar and electric vehicles. With the help of government-funding, trials are underway to investigate whether neighbourhood batteries can be operated in a way that aligns with what has been promised of this technology i.e. to support decarbonisation, allow more renewables and to make energy cheaper and more local.

One aspect of neighbourhood battery operational models that will impact outcomes for all stakeholders (including the grid) is the network tariffs they will pay. Network tariffs are fees charged by Distribution Network Service Providers (DNSPs) for the use of the electricity network. These tariffs fund the maintenance and upgrade of the grid and can influence the behaviour of both consumers and assets (like batteries) and thereby impact energy management on the network.

For the batteries rolling out under government-funded trials, at least five DNSPs across the National Energy Market (NEM) have introduced trial tariffs with varied features, such as energy charges with flat or time-of-use rates, demand charges with time-varying or seasonal rates and capacity charges. Here we report on our analysis of whether batteries operating with these network tariffs are likely to result in benefits for the grid and for consumers. Our assessment reviewed five trial tariffs offered nationwide, analysing their impact on peak demand and financial outcomes for stakeholders.

Our results revealed three findings that could influence the design of neighbourhood tariffs moving forward. First, tariffs with a demand charge can help reduce peak system demand and those without a demand charge can inadvertently increase peak demand, as operations prioritise revenue generation. Second, two-way tariffs appear to be a good mechanism for incentivising solar soaking (charging during solar hours, discharging during the evening peak), with significant revenue being paid to the battery operator. Finally, tariffs did not impact how much locally generated rooftop solar provided the total electricity requirements of households (local solar utilisation).

As next steps and recommendations, we advocate for a co-design approach between government, regulators, researchers, community, and network businesses to refine neighbourhood battery tariffs, informed by our analysis of current trial tariffs.

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[1] Also known as community batteries however we reserve the term community batteries for those that are owned and/or governed by community

Background

Neighbourhood batteries (NBs) are more than just a technological advancement; they have the potential to be a community-focused solution that resonates with the public's growing preference for fair, shared and sustainable energy practices. The concept of 'keeping energy local' is particularly appealing as it aligns with the broader societal movement towards energy democratisation and the desire to retain the benefits of renewable energy generation within communities (Ransan-Cooper, Shaw et al. 2022).

Our previous work has provided an in-depth examination of the potential role of neighbourhood batteries in Australian energy markets, highlighting the benefits of improved grid stability and increased local consumption of solar energy (He, Bardwell et al. 2023). Work in Europe also identified technical and economic benefits of community storage over household batteries, including a reduction in the levelised cost of battery storage by 27% (Parra, Norman et al. 2017). In addition, new opportunities for citizen participation within communities and increased awareness of energy consumption and environmental impacts were highlighted (Parra, Swierczynski et al. 2017). However, despite potential technical, economic and social benefits of neighbourhood batteries, knowledge gaps still exist around how to implement neighbourhood batteries in the way that delivers on their promised benefits.

For example, work done by Muller and Welpe found that, despite the reduced levelised cost of energy, a model for the shared usage of storage by multiple households has yet to emerge. They investigated eight demonstration projects in Germany and Western Australia with respect to potential business models and barriers, and found that in-front-of-meter models face significant barriers largely relating to tariffs (Müller and Welpe 2018).

In Australia, innovative distribution network tariffs are being trialed, that aim to incentivise the flexible behaviour of distributed resources and equitably represent the cost implications of network utilisation in systems characterized by bidirectional electrical flows. Tariffs for battery storage ought to account for the utilisation costs and the prospective cost mitigation they can offer to the network by addressing the complexities introduced by widespread solar integration. Some of these tariffs have a two-way structure that either levies charges or disburses payments to the battery operators, depending on their impact on the network. Alternatively, achieving network support from battery storage operators could be facilitated through Network Agreements (see Citipower 2024 for recent discussion), which bypass tariff mechanisms while aiming to mirror the influence of consumer consumption patterns on the network's prospective expenses.

Another tariff feature being trialled for neighbourhood batteries is a demand charge component, which charges consumers based on their maximum demand rather than total usage. Although the goal is to lead to a more efficient use of network infrastructure and reduce peak demand pressures, recent work suggested that demand tariffs were counterproductive because the user peaks targeted by demand charges often do not overlap with system peaks (El Gohary, Stikvoort et al. 2023). Overall, the evolution of distribution network tariffs is consistent with a changing energy landscape characterised by the rise of renewables, customer energy resources and battery storage. The design of such tariffs aims to recognise the critical role that neighbourhood batteries and other distributed resources could play in maximising our utilisation of network capacity.

While the methodologies and regulatory environments differ, the move towards more sophisticated tariff structures, such as time-of-use (TOU) energy charges and time-varying demand charge tariffs, is a common theme globally. The current study contributes to this effort by attempting to quantify (with simulations), whether these tariff structures, as adopted by neighbourhood battery trial tariffs, do contribute to desired outcomes for all stakeholders. Importantly, neighbourhood battery network tariffs must be structured to ensure the batteries do not imposing undue financial burdens on those who do not benefit directly from the battery. The Australian experience, with its significant deployment of solar PV and government-funded neighbourhood battery trials, can provide valuable insights into the efficacy and stakeholder impacts of distribution network tariff reforms.

Methodology

Our assessment reviewed five trial network tariffs designed specifically for neighbourhood batteries across Australia. We categorised these different tariffs according to their main features:

1. one-way flat rate
2. two-way TOU rates without demand charges
3. two-way flat rate with one-way seasonal demand charge and a capacity charge
4. two-way TOU rates with two-way time-varying demand charges

The detailed explanations of these tariff components and their actual rates are provided in the Appendix.

We analysed the impact of the trial tariffs on peak demand, financial outcomes for stakeholders, and grid support. The simulation was carried out according to the plan outlined in Figure 1 with full details for the methods given in Table A. 1 in the Appendix.

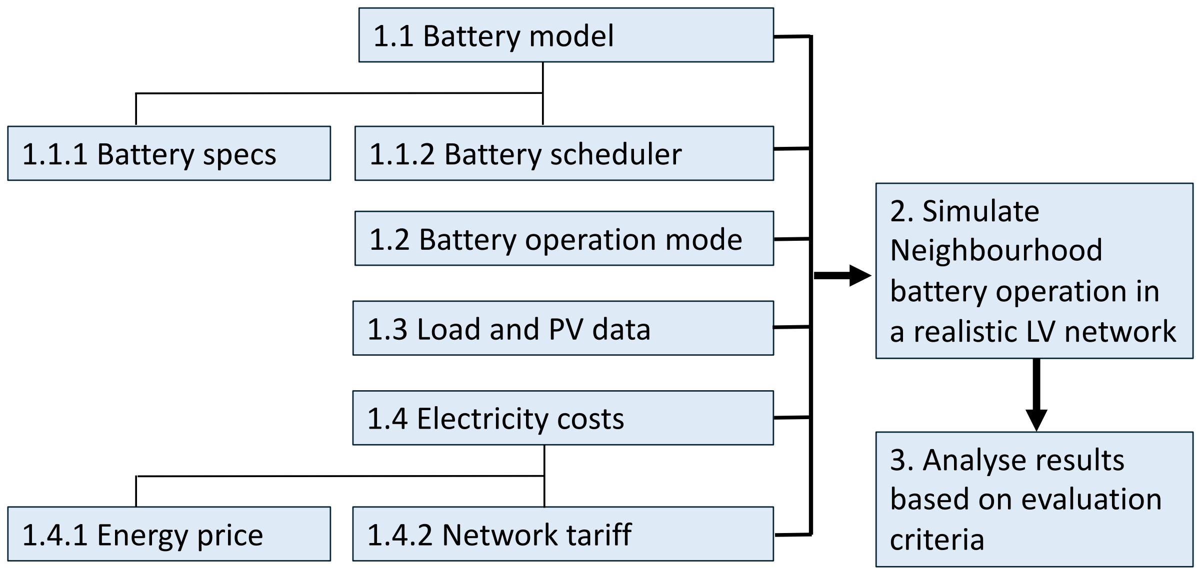


Figure 1: Battery, load and cost data was fed into a simulation of a neighbourhood battery in a realistic low-voltage (LV) network. The results were evaluation based on evaluation criteria as outlined in Table A. 1 in the Appendix.

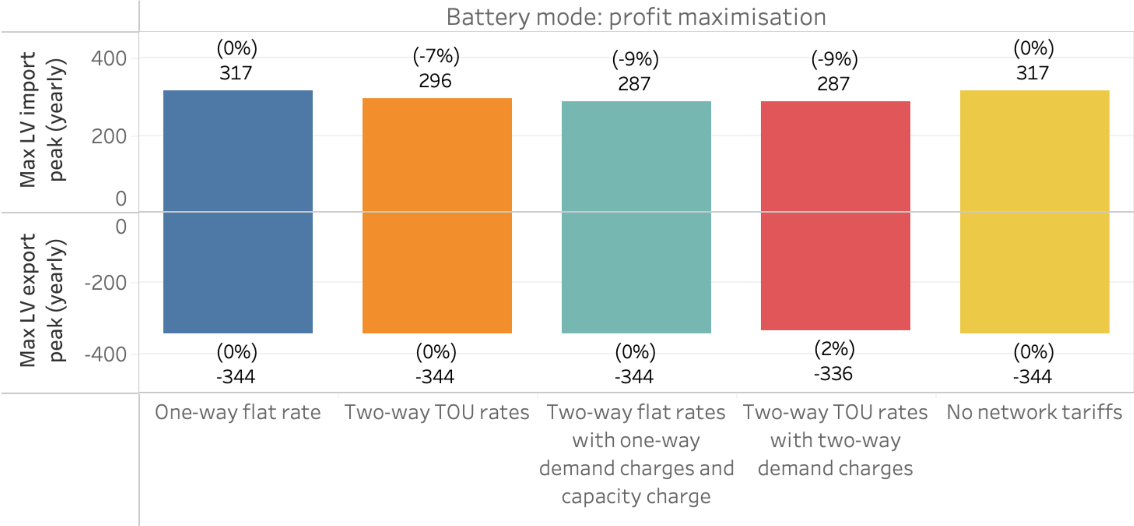
Results

Results are presented for operating a 200 kWh / 100 kW community battery for 100 households where 75 of them had rooftop solar. This scenario is chosen because it closely matches typically battery operation in practice in Australia. Results for other scenarios studied are included in the Appendix.

There were three main findings:

(1) Tariffs with a demand charge did result in decreased system peak demand. For example, as shown in

(2)



(3)

(4) Figure 2, when the battery operated to maximise profit (profit maximisation mode), the two-way time-of-use (TOU) tariff with two-way demand charges significantly reduced the import peak demand (by 9%), whereas the two-way tariffs without demand charges reduced the import peak demand by 7%. Note that, when the battery was not operating to maximise profit (i.e. it was in the balanced or solar soaking modes), there was no difference between peak demand between the tariffs.

In scenarios where the battery capacity was relatively large (e.g. 200kWh for 50 houses where 25% had rooftop solar) and a two-way demand charge was applied, the battery did have an impact on reducing the export peak.

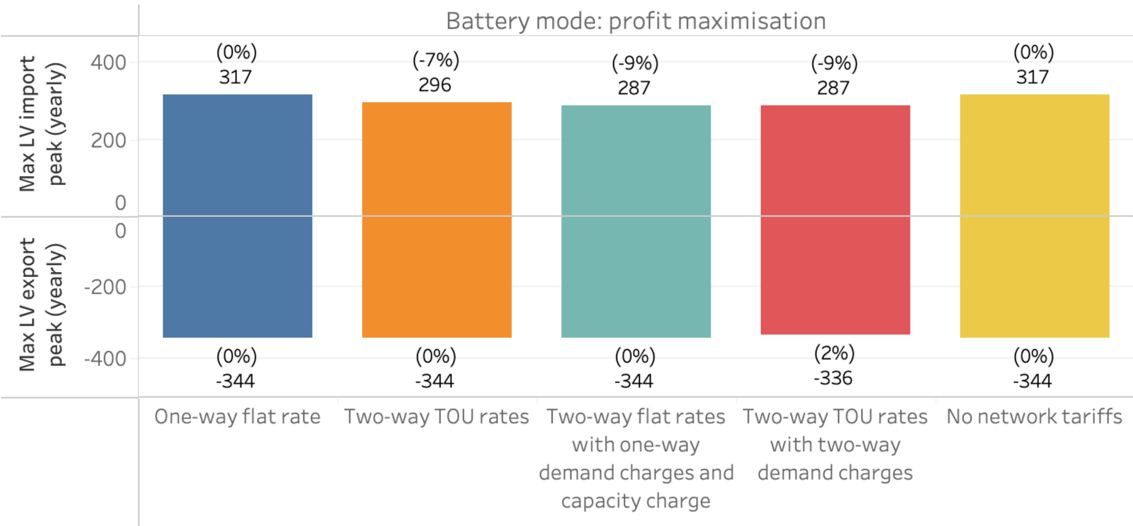


Figure 2: When the battery was operating to maximise profit, two-way time-of-use (TOU) rates with two-way demand charges reduced import peak demand by 7-10%.

(5) Two-way tariffs incentivise solar soaking and return revenue to the battery owner. We found that two-way tariffs (with or without demand charges) could offer higher incentives for batteries to charge during solar hours (around the mid-day) and discharge in high-demand times (in the evening).

This result held for all scenarios tested and was particularly pronounced for the battery operating in solar soaking mode. The result is of note as solar soaking is not typically a financially attractive mode, and therefore increased revenue to the battery owner makes it a more attractive option. The scenario corresponding to the neighbourhood battery operating in balanced mode is shown in

Figure 3.

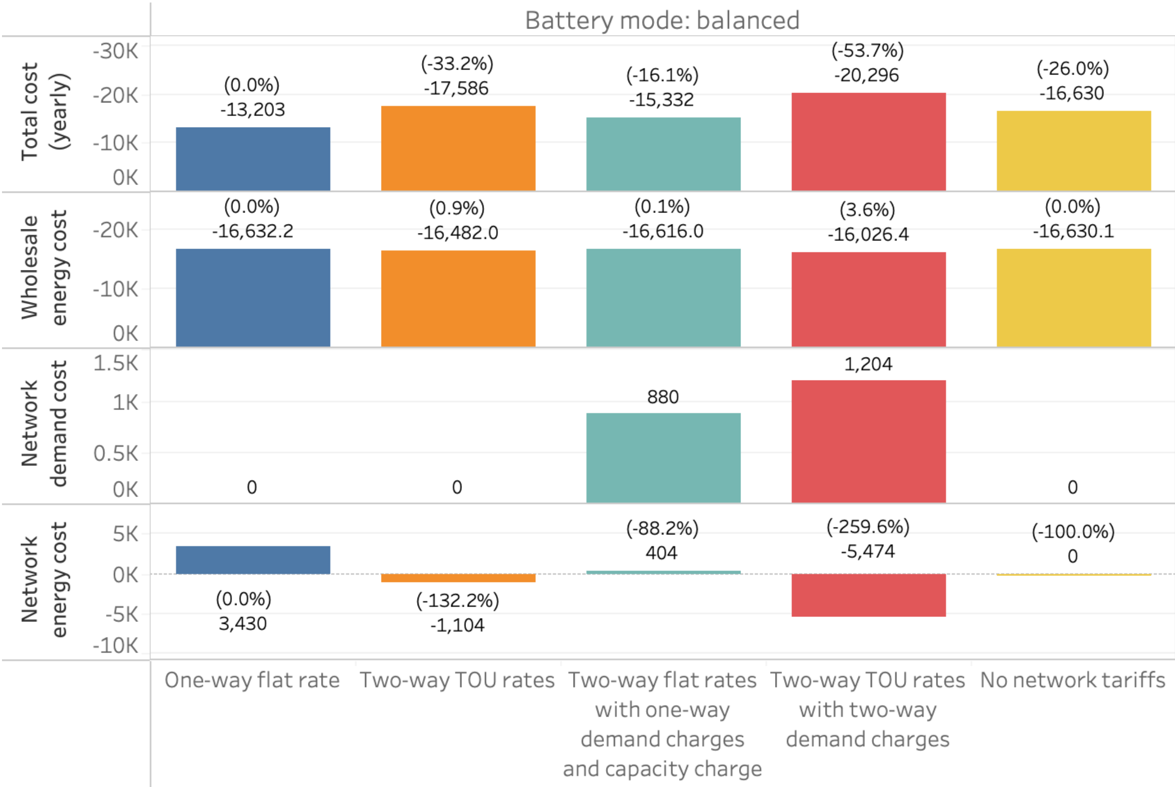


Figure 3: With a neighbourhood battery operating in balanced mode, a two-way TOU network tariff resulted in at least 33% more revenue for the battery operator, compared to the one-way flat rate.

(6) All tariffs resulted in a similar level of local solar utilisation. Under the condition of operating the battery at maximum one cycle per day, all tariffs resulted in a similar level

of solar utilisation in all modes. In the balanced and solar soaking modes, the average solar *self-sufficiency* (SS) and *solar self-consumption* (SSC) were the same for all tariffs; only in the profit maximisation mode, two-way TOU rates with demand charges) slightly increased the SS or SSC by 3-5%. Note that the detailed explanations on SS and SSC are provided in Table A. 1 in the Appendix.

However, when the battery size was relatively large, for example, using a 200-kWh battery for just 50 households where 25% of them had rooftop solar, operating in profit maximisation mode, the two-way TOU rates with two-way demand charges did increase SSC by 2% and SS by 7%. In contrast, SSC and SS reduced by 2-6% with the battery operating in balanced mode. This means, when the battery size is large enough to accommodate all the solar generation in the local network while having additional capacity for making revenue through arbitrage or taking advantages of the two-way TOU rates, the choice of tariffs would have a more substantial impact on the local solar utilisation rate.

Summary, next steps and recommendations

Further work is required to investigate whether these results hold across a range of network scenarios, including when the battery is operating with real-world imperfect forecasts. In practice, imperfect forecasts will likely reduce the efficacy of network tariff impacts on battery behaviour. In addition, some of the network benefits we have observed here could also be achieved with the use of *dynamic operating envelopes* (DOEs), as identified by the DEIP analysis (2022). Further work is required to investigate the benefits of neighbourhood battery trial tariffs in network scenarios that are also utilising DOEs.

Our results, however, do shed light on the efficacy and stakeholder impacts of the current phase of neighbourhood battery trial network tariffs. In particular, we observed that demand charges did result in small decreases in system peak demand and that two-way tariffs did incentivise batteries to charge during solar hours (around the mid-day) and discharge in high-demand times (in the evening), also returning revenue to the battery owner.

In addition to further work outlined above, we advocate for a collaborative approach between researchers, governments and network businesses to refine the next phase of neighbourhood battery tariffs, informed by this and future analyses of current trial tariffs, particularly as some network businesses are currently preparing tariffs for their next regulatory submission phase.

Appendix:

This appendix provides additional details on the simulation methods and the tariffs chosen for this study.

Full details of methodology, with numbering corresponding to Figure 1	
1. Battery specs	Capacity = 100 – 300 kWh, power = 50 – 150 kW, round-trip efficiency = 0.85, depth of discharge = 90%, maximum daily cycle = 1 Note that the power is also the maximum charge/discharge rate of the battery
2. Battery scheduler	Based on our in-house battery optimisation software (Python, Pyomo) and the Gurobi solver, the best charge and discharge times and demand profile for the battery are found. The number of households (with loads only and both loads and PVs), the wholesale prices, the network tariffs, and the operation objectives were all given.
3. Battery operation mode	Given the wholesale spot prices and the battery network tariffs, the battery is optimally charged and discharged to achieve the following objectives in each of the three different battery operation modes (strategies): 1) solar soaking: generally charging during solar hours and discharging during the evening peak, to minimise the import and export power of the LV network (including all households and the battery) for each day. 2) profit maximisation: to maximise the revenues or minimise the costs for the battery owner for each day. 3) balanced: to maximise the balance between the needs for solar soaking and profit maximisation.
4. Load and PV data	Use historical loads and PV output measurements from the 2018 NextGen dataset for Canberra (Shaw, Sturmberg et al. 2019). Whilst data is available from 2016 onwards, the simulation inputs were taken from a cleaned 2018 subset. Positive load convention was followed such that any negative loads or positive solar PV data were removed from the dataset. Additionally, where data was sparse or discontinuous these days were also removed (Shaw, Sturmberg et al. 2019). Load profiles at 5-minute intervals as well as PV outputs were then assigned to each household on the network.
5. Energy prices	Use the historical spot prices in 2022 from NSW
6. Network tariffs	Trial network tariffs for community batteries from the five DNSPs -- Ausgrid, CitiPower/PowerCor/United Energy, Essential Energy, EvoEnergy, and Jemena. 1) Use the explanations or descriptions found in the tariff notifications published in 2024 by each DNSP at the AER website. 2) Categorise the trial tariffs based on their components. Identified four categories (i) Flat/Fixed rate only (ii) Two-way TOU rates only (iii) Two-way flat rate with demand charges (import only, vary with season) and capacity charge and (iv) Two-way TOU rates with demand charges (for both import and export, vary the time of the day) Use the actual rates, published in the tariff notifications, for these tariff components from the five DNSPs (see further information below in the 'Neighbourhood battery trial network tariffs' section).

7. Analyse results based on evaluation criteria	Design criteria for evaluating the impact of network tariffs on local energy management and cost outcomes for the battery owner: 1) Local energy management: the maximum 5-min import and export power of the LV network (including all households and the battery) over the yearly horizon. 2) Solar utilisation: self-solar consumption (SSC) and self-sufficiency (SS) 3) SSC measures the amount of local solar generation that is consumed by all households and the battery in the local network instead of being exported to the grid. 4) SS measures the amount of local demand that are satisfied by the local generation in the LV network, instead of being met by the imported energy from the grid. 5) Cost and benefits: total cost / revenue for the battery owner (including the wholesale energy cost and the network costs). Compare the results of different types of tariffs using those criteria. • Use the battery network tariff that only includes a flat rate as the base case, • Compare other types of tariffs with the base tariff case, to evaluate if one is better or worse at managing peak power, utilisation local solar generation and providing financial gains for the battery owner. • Compare the results of scheduling the battery against the wholesale spot prices only without considering any battery network tariffs, with those that consider both the wholesale spot prices and the battery network tariffs.
8. Simulation time horizon	Simulations were run for a full year, using 2022 spot price data. The battery optimised its scheduling based on a rolling horizon. This meant that the optimisation was conducted for each individual day, until all days in 2022 had been simulated. The optimisation was based on perfect forecasting. Realistically, imperfect forecasts will result in worse outcomes for battery performance.

Table A. 1 Details of the simulation methods

Neighbourhood battery trial network tariffs

A network tariff is a cost charged by Distribution Network Service Providers (DNSPs) to users of the electricity network which should reflect how their current use of the network will impact future network infrastructure costs. This cost is used for building, operating, and maintaining the poles and wires in the network for transporting electricity.

Recently, the Australian Energy Regulator has initiated network tariff reform with a focus of "allowing distributed energy resources (DER) such as solar PV, batteries and electric vehicles to be integrated onto the grid as efficiently as possible". As a result, five DNSPs have proposed different trial tariffs specifically for neighbourhood batteries. These DNSPs include Ausgrid, CitiPower/PowerCor/United Energy, Jemena, EvoEnergy and Essential Energy. Despite the differences in these trail tariffs, there are four common components:

1) *Fixed charges*: a fixed daily cost that consumers pay regardless of their electricity usage.

2) *Energy charges*: a cost that is proportional to the total electricity usage of the consumer (measure in kWh).
3) *Demand charges*: a cost that is proportional to the maximum power required by the consumer at certain time periods of a day (e.g. during the high-demand hours from 5pm to 8pm)
4) *Capacity charges*: a cost that is proportional to the maximum power required by the consumer at any time of a day.

The capacity charge is similar to the demand charge; however, it is based on the maximum demand at any time, which determines the minimum capacity for the electricity generation and transportation of a power system. Note that another common component among these tariffs is a critical or peak event charge, which is a cost associated with the energy consumption during critical times, such as in an extreme hot/cold day. These critical time periods are hard to predict and can determined differently by each DNSP based on their unique network conditions. Therefore, we do not include this component in our study.

The design for each of these components varies with DNSPs. For example:

- An energy charge can be designed as a one-way or two-way flat rate (see Figure A. 1) and a two-way time-of-use (TOU) rates (see Figure A. 2).
- A demand charge (DC) can be a rate that varies with seasons (see Figure A. 3) or with the time of the day (see Figure A. 4). A DC can also be applied to one direction (such as to import power only) or two directions (such as to both import and export power). Furthermore, a DC can be a single rate or a block rate that increased with the maximum power (see Figure A. 5).
- A capacity charge is often a flat rate that is based on the maximum power over a rolling time window, such as the current week, the current month, or the previous 13 months.

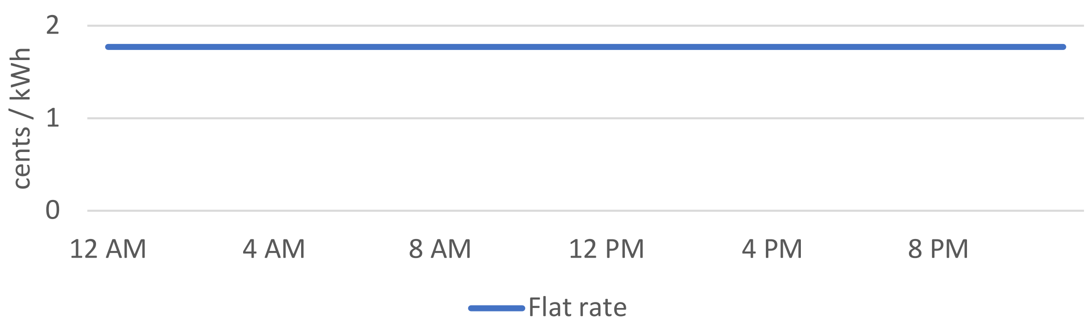


Figure A. 1 Flat energy charge rate which can be applied to import and/or export energy.

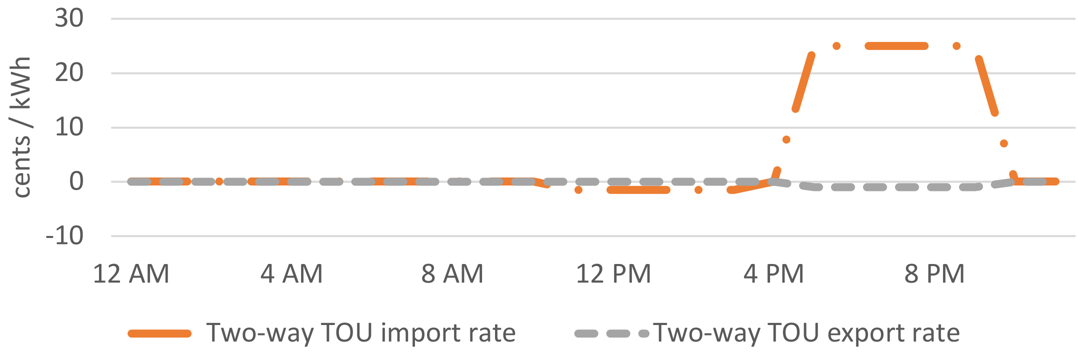


Figure A. 2 Two-way TOU energy charge rates.

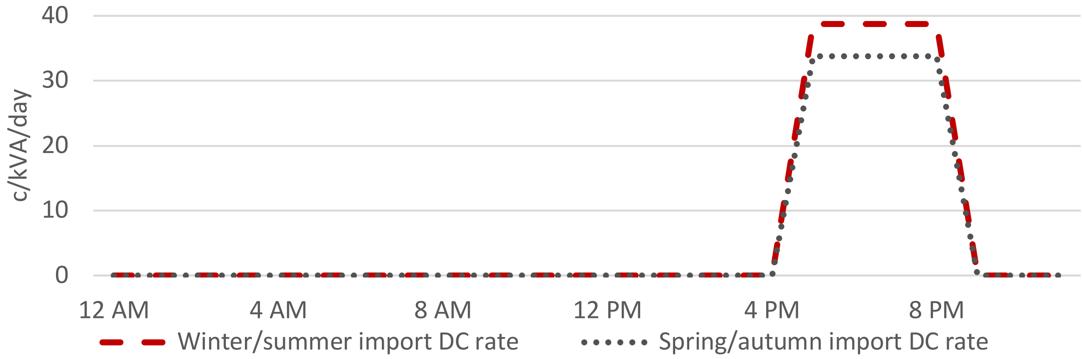


Figure A. 3 Import demand charge rate that varies with seasons.

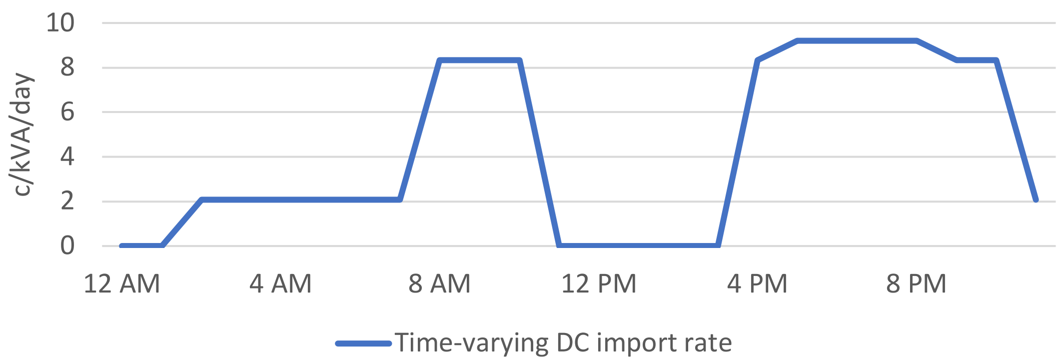


Figure A. 4 Import demand charge rate that varies with the time of the day.

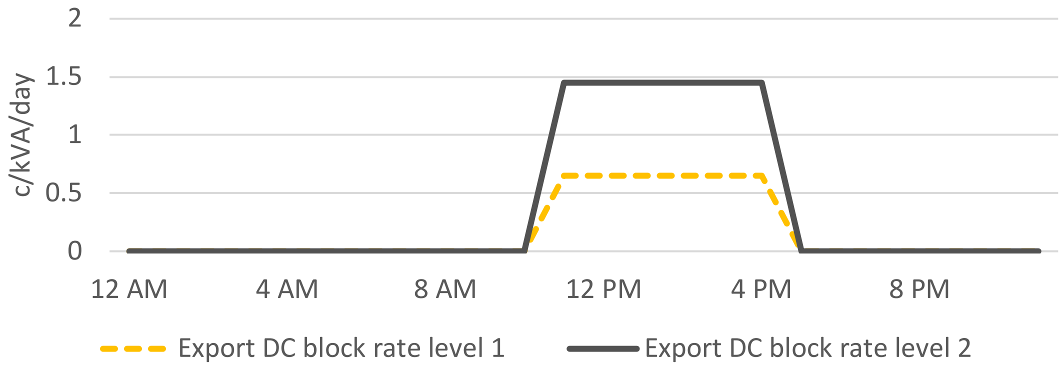


Figure A. 5 Export demand charge block rates. The level 1 rate is applied to export power less than 3kW, and the level 2 rate is applied to any export power above 3kW.

For comparison, we summarised the component design of the battery trial tariffs proposed by the five different DNSPs as Table A. 22.

DNSP	Import energy charge	Export energy charge	Import demand charge	Export demand charge	Capacity charge
Ausgrid	Flat	-	-	-	-
CitiPower/ PowerCor/ United Energy	TOU	TOU	-	-	-
Jemena	TOU	TOU	4-7pm in summer only	-	-
EvoEnergy	Flat	Flat	Seasonal	-	Based on the previous 13 months
Essential Energy	TOU	TOU	Time-varying	Time-varying block rates	-

Table A. 2 Component design of the battery trial tariffs from the five different DNSPs (exluding the critical or peak even charges).

Full details on the structures of these tariffs including the actual rates, which were used in this study, can be found in the following links:

- Ausgrid: https://www.aer.gov.au/industry/networks/pricing-proposals/ausgrid-annual-pricing-2023-24
- CitiPower/PowerCor/United Energy: https://www.aer.gov.au/industry/networks/pricing-proposals/citipower-annual-pricing-2023-24
- Jemena: https://www.jemena.com.au/electricity/jemena-electricity-network/network-information/trial-tarrifs/
- EvoEnergy: https://www.aer.gov.au/industry/networks/pricing-proposals/evoenergy-annual-pricing-2023-24
- Essential Energy: https://www.aer.gov.au/industry/networks/pricing-proposals/essential-energy-annual-pricing-2023-24

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