Neighbourhood batteries in Australia

Australia | Sometimes called 'community batteries,' energy storage systems are being installed at neighbourhood level in Australia. Experts from the Australian National University explain how this type of battery storage can benefit a very wide range of stakeholders.

Credit: Western Power

An example of a neighbourhood battery system in West Australia, installed in a trial by Western Power.

As Australia transitions its electricity supply away from fossil fuel-powered generators to renewable sources of energy, neighbourhood batteries are becoming an increasingly popular form of storage. There are more than one dozen neighbourhood battery projects currently underway across Australia, with a range of ownership and operation models.

It is now, in the early days of neighbourhood battery research development, design and demonstration that we can evaluate the various models and trade-offs inherent in these models. Technology can end up not meeting user needs, or result in negative unintended consequences if we don't step back to understand their impacts early on.

In the Battery Storage and Grid Integration Program at the Australian National University we have been conducting numerous studies that delve into the socio-techno-economic aspects of neighbourhood batteries. Our research has revealed that this type of battery can provide a range of benefits for all energy stakeholders, be they energy network operators, energy retailers, market operators, customers, governments, or local councils.

What these batteries have in common is that they are all located close to customers, connected to the distribution network, and can provide stored energy for up to hundreds of homes. They range in size from a wardrobe to a shipping container, have power capacities of about 0.1 - 5MW and complement household and utility-scale batteries.

Reversing a trend of 'haves and have-nots'

What makes neighbourhood batteries a particularly interesting form of energy storage is that they have the potential to address energy equity and provide benefits to all energy users. Some groups of people, particularly renters and those who do not have solar panels on their rooftops, but also people who might be socially and digitally isolated could all benefit from neighbourhood batteries.

These benefits could be economical, or an increased sense of autonomy and control over their local energy management. This contrasts with how rooftop solar has played out in the Australian context.

Historically residential solar has been a tale of the 'haves' and the 'have-nots'. Those who can afford to put solar panels on their roof and those who cannot.

Household solar uptake has not happened alongside a broader conversation about what kind of energy system we want. Neighbourhood batteries can hopefully spark those conversations. Our research tells us that people really want to be a part of these conversations and have long felt disconnected from energy decisions that affect them.

Neighbourhood batteries are sometimes referred to as 'community batteries' or 'community energy storage'. We elect not to use these terms because the word 'community' implies a degree of community involvement.

Some neighbourhood battery projects absolutely do have this element and we suggest community involvement is required as a principle. It is also the case that other models are allowed in Australia's current regulatory system that requires little or no involvement from the community. To encompass all models, we use the term *neighbourhood batteries.*

Australia, the distributed energy resources superstar

Australia leads the world in the uptake of rooftop solar, per capita, with one in four homes with residential PV[1]. Three million solar systems have been installed nationwide[2], that's nearly 1kW of panels per person. It is the enthusiastic adoption of rooftop solar by people that has made the country a distributed energy resources superstar.

Beginning a decade ago, the high uptake of solar PV amongst Australian householders was in response to feed-in tariffs and government rebates. It simply made good financial sense to install solar panels on your roof. A second reason is environmental in nature. Customers have been installing PV in recognition of the important role that more renewable generation will play in addressing the existential crisis that is climate change. A third reason is that Australians are seeking greater energy independence from a system that has made them feel disenfranchised.

Our work has revealed that many people feel a motivation that energy decision makers are overlooking. They feel the energy transition is not happening fast enough and in the way they would like it to. Buying solar is a way to show their defiance and send a signal to those in power that they are not happy with the way the energy transition is unfolding. For these householders, the financial benefits are just a bonus.

Integrating this vast amount of solar generation is a major challenge for network operators and there are several ways Australia is tackling this problem from smart software solutions, utility-scale storage, pumped storage and various demand response and other market mechanisms.

In Australia, also notably in the US states of California and Texas and many parts of Europe, grid operators are resorting to solar curtailment when there is not enough transmission capacity to cope with the generation of renewable energy. The infamous 'duck curve' graph indicates the discrepancy between peak electricity demand versus peak solar energy production. Neighbourhood batteries have a role to play in capturing the excess energy generation and storing it until it is needed. But this is just one of the benefits of this type of battery.

Defining and assessing the benefits

The ability to provide benefits to many stakeholders is one of the key reasons why we felt it was important to comprehensively investigate the opportunities for neighbourhood batteries. There are four key elements that describe a range of possible battery models[3].

It is important to remember that benefits have different definitions. The energy sector is used to thinking about benefits in terms of return on investment. But other stakeholders might be more concerned about decarbonisation, or whether the battery can make the community more resilient or even whether the battery could spark a conversation about collective opportunities for demand response.

With this in mind, the elements that will likely affect how the benefits are defined and accessed include:

- Battery ownership – who will own the battery, and what regulatory considerations might arise due to ownership? Crucially, how might battery ownership influence the prioritisation of benefits to different stakeholders?
- Stakeholder participation – who is a stakeholder in the battery's operation, and what is their legal and operational relationship with the battery? How do stakeholders benefit from their participation, and what technology is necessary to enable the battery operation?
- Network tariffs – what network tariffs are applied to energy flows into and out of the neighbourhood battery, and how do network tariffs unlock or impact the benefits that can be delivered to stakeholders?
- Services delivered – what market services, such as energy arbitrage and frequency support, can neighbourhood batteries deliver? What non-market services, such as network support (demand response, voltage regulation), do neighbourhood batteries deliver? How can services be value stacked to maximise the battery's utilisation and cost-effectiveness? Or maybe, due to community discussion, the most 'optimal' outcome may actually be an optimisation they can understand, meaning, perhaps not all value streams will be accessed.

> "The energy sector is used to thinking about benefits in terms of return on investment. But other stakeholders might be more concerned about...whether the battery can make the community more resilient."

By undertaking a socio-techno-economic analysis of various permutations of these four key considerations, we have been able to assess how different neighbourhood batteries create value for energy users, distribution networks, electricity retailers and the broader electricity system.

Our work has so far revealed that neighbourhood batteries can deliver five essential benefits. They can:

1. Improve the fairness of the energy system
2. Build trust in the energy system by sharing value transparently
3. Increase the hosting capacity of the network
4. Bolster local resilience, including socially, economically, and electrically
5. Be cost effective by delivering services to many stakeholders.

We note that more benefits may become clear as we roll out this technology at scale.

Value-sensitive design

As part of our social research[4] we conducted interviews and forums with industry stakeholders and members of the public. A general theme borne out of much of our research is that trust in the electricity sector is low. This finding alone should stimulate some reflection from key actors in the sector about how we could make the energy system more transparent and include people in key decisions.

People's interest in technology is usually multi-dimensional and reflects their experiences and needs. Usually affordability is only one element – for example, our participants were highly concerned about battery life-cycle, promoting local energy use, reducing carbon emissions, questions of fairness and how this technology would support the broader energy transition to renewables.

After we conducted our social research, we then considered different battery optimisation designs that reflected these different values.

The ***carbon-savings algorithm***, for example, operates the battery to minimise the carbon emissions of the neighbourhood's energy generation mix. A consistent theme among householders was the value of batteries in enabling more renewables and the decarbonisation of the electricity system. This algorithm might be chosen, for example, by a city community who choose to pay a little more for their energy in order to prioritise local decarbonisation.

For the ***self-sufficiency algorithm***, the battery operates to maximise the energy independence of the community, by storing locally produced solar energy. Algorithm design here was influenced by the community's enthusiasm for the idea

Credit: Horizon Power

582kW / 583kWh battery storage system in the remote town of Marble Bar deployed this year by state government-owned electricity supplier Horizon Power.

of local generation and local use of solar resources located in their own neighbourhoods. This algorithm might be chosen, for example, by a community from a coastal region of Australia which is at risk of isolation from the main grid because of bushfire or other natural disasters.

The ***timer algorithm*** instructs the battery to follow a simple fixed daily schedule. Although not the financially optimal choice, we tested this algorithm in response to concerns that were voiced to us about the 'gaming' of the energy market by incumbents. This algorithm is easy for non-experts to understand and makes it easy to monitor the distribution of benefits. Stakeholders often expressed a desire for transparency and explainability, and a desire for autonomy and control over their energy choices.

In practice, battery algorithms can be designed to optimise for more than a single objective for example, financial costs and decarbonisation values. However, we demonstrate that multiple values cannot always simply be 'value stacked' in an algorithm, rather, some values are inescapably in tension with one another, and trade-offs are required.

These trade-offs will be inherently political (influenced by different values), particularly because the values being traded off may be based on unrelated metrics (for example, dollars versus algorithm explainability) and some are not naturally quantifiable. For example, it is easy to design an algorithm to maximise revenue for a battery owner but challenging to consider how to design an algorithm that maximises energy users' autonomy and control. As we conclude in our paper[4], this will inevitably bias the design of algorithms towards the easily quantifiable.

The bias and explainability of neighbourhood battery algorithms

Research on the inherent biases of algorithms has grown substantially over the past decade, yet these are relatively new issues to energy researchers like us. Our work highlights that it will be essential to consider how these issues are explicitly encoded into the millions of devices that will underpin our future electricity grid. How can we do this in practice? In our paper, '*Applying responsible algorithm design to neighbourhood-scale batteries in Australia*'[4], we discuss the need for digital energy technologies to be developed through an 'algorithmic accountability in action' approach that aligns the behaviour of these technologies with public values.

Through our research we have demonstrated that battery control algorithms can be optimised to meet diverse needs however algorithms may also perpetuate bias and generate unfair outcomes. We raised three systemic concerns that we believe had been previously overlooked.

The first is the potential bias of algorithms to lead us towards easily quantified metrics, for example profits, costs, and voltage management. Our second concern relates to explainability. Even when algorithms provide simplified explanation, such as arbitrage to 'buy low and sell high', we saw that these methods can be applied to vastly different outcomes of battery profit, communal bill reductions or carbon emissions reductions.

A consequence of this opacity is that while financial approaches may claim to produce public benefit through improved market efficiencies and lower market prices, these claims may, in practice be 'gamed'. Even with regulatory controls and oversight, our research reveals it may anyway face backlash from the public in contexts where trust is low. Indeed, it is possible that the non-'optimal' timer algorithms may meet public needs because they relieve concerns about complexity and a lack of transparency.

This brings us to the third systemic concern around implications for community control. There is an important paradox here. Namely, the reliance on algorithms could both serve to reveal and open up the 'black box' of decision-making in energy systems through using methods to engage stakeholders in dialogue about values and trade-offs for the battery optimisation (enabled by the fact that some values are quantifiable).

At the same time, the complexity of optimisation algorithms and the likelihood in the Australian context for these to be developed by the private sector, without consideration of the public's views and values could further exclude stakeholders from understanding and participating in the energy system. Likewise, there remain important questions about the use of any behind-the-meter load data used in battery optimisation, in terms of data ownership and use(s).

Our findings emphasise the need to take a holistic view of the values and assumptions embodied in algorithms that will affect perceptions of the benefits and risks of storage technologies for individual users as well as other actors in the energy system. We believe this requires truly interdisciplinary work, as 'good modelling cannot be done by modellers alone. It is a social activity'6.

For new energy technologies, there are numerous methods for exploring potential effects of technologies, but it is key for these to be explored within specific cultural contexts. The need to anticipate and reflect public concerns in battery optimisation design is likely to be especially acute in privatised energy systems where key incumbents must prioritise shareholder values, over overarching public benefits or concerns.

The economics of neighbourhood batteries

The issue of network tariff reform has historically been a contentious one in Australia, in the context of high uptake of household solar. We have studied the operation of neighbourhood batteries under a range of local network tariff models, using current Australian electricity prices and current network prices as a reference.

Artist's impression of a neighbourhood battery system on a street in Melbourne, Victoria.

Credit: Pixii.

Our modelling shows that neighbourhood batteries would only be financially feasible if the local network tariff was discounted. This is due to the tariff applying to both the charging and discharging of the battery, meaning the system is double-charged.

Previous proposals to address this issue have generally either applied a discount to network tariffs for local energy flows or created a secondary energy market for peer-to-peer transactions. The former is expected to result in a zero-sum wealth transfer between networks and customers, and the latter has faced implementation and regulatory complexities.

Our modelling[5], however, demonstrates that a discounted local use of system (LUOS) network tariff could be introduced without the expected zero-sum wealth transfer, if a neighbourhood battery is included in the local system. This is due to the increased number of transactions on the network as the battery charges and discharges, such that the network receives the same revenue even though the network tariff is discounted. Network charges incurred by the neighbourhood battery owner can be offset by the revenue earnt from energy arbitrage. In this way, all stakeholders (network, customers, battery owner) can be financially better off compared to a system with no neighbourhood battery and the normal network tariff.

The clear recommendation from our analysis is that the price of LUOS needs to be less than half of conventional distribution network tariffs, allowing for mutually beneficial economic outcomes for all stakeholders.

The Neighbourhood Battery Initiative (NBI)

In 2021, the Victorian Government of Australia funded the Neighbourhood Battery Initiative (NBI) with the goal of demonstrating how this technology can support the energy transition.

In partnership with the NBI, the Battery Storage and Grid Integration Program is developing a framework that evaluates the social, technical and economic impacts of neighbourhood batteries, as well as developing a set of Neighbourhood Battery Guidelines.

These guidelines will focus on community engagement, partnerships and contractual arrangements, customer participation and technical specifications to deliver the full suite of battery services. Along with guidance for working with networks to identify locations where neighbourhood batteries could provide network support.

One of the projects funded by the NBI is Melbourne's first inner-suburban neighbourhood battery project; the Melbourne 'solar sponge' initiative. This multi-partnered project includes the not-for-profit organisation Yarra Energy Foundation, electricity network Citipower, City of Yarra local council and the ANU Battery Storage and Grid Integration Program.

The Yarra Energy Foundation is consulting extensively with the local community, holding numerous information and Q&A sessions, organising meetings, drop-in sessions and public consultation sessions in an effort to learn how the community wants to embrace batteries and energy storage solutions.

Neighbourhood batteries are providing an opportunity to shift to cheap, net-zero local energy. As the early trials into this technology begin, we need to ensure that we are focused on the best outcomes for energy users and the environment. Together, researchers like us can work with decision makers, communities, network operators, retailers and other stakeholders to ensure that we do not bake in technology designs that exclude and create community backlash, but instead reconnect people to the energy transition that they want.

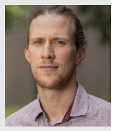
References

1. Data from Clean Energy Regulator, analysed by CSIRO
2. PV in Australia Report for 2020, published by International Energy Agency with ARENA and Australian PV Institute
3. Implementing community-scale batteries, final report for ARENA-funded Community Models for deploying and Operating DER project, ANU
4. Applying responsible algorithm design to neighbourhood-scale batteries in Australia, ANU, published in Nature Energy, July 2021
5. A mutually beneficial approach to electricity network pricing in the presence of large amounts of solar power and community-scale energy storage, ANU, published in Energy Policy, Vol 159, December 2021
6. Saltelli, A. et al. Five ways to ensure that models serve society: a manifesto. Nature 582, 482–484 (2020).

Authors

Sarah Wilson is communications manager for the Battery Storage and Grid Integration Program at the Australian National University. Sarah has close to 20 years' experience working in Australia and internationally with scientists and researchers, assisting them to communicate their work to a broad audience.

Hedda Ransan-Cooper leads the social research at the Battery Storage and Grid Integration Program at the Australian National Unversity. Her research covers the social, political and cultural dimensions of the decentralised energy transition.



Bjorn Sturmberg is a research leader in the Battery Storage and Grid Integration Program at the Australian National University where he is engaged in projects on grid integration of distributed energy resources and electric vehicles, advanced sensors, power system security, energy analytics, policy and regulations, and social acceptance of new energy technology.

Lachlan Blackhall is entrepreneurial fellow and head, Battery Storage and Grid Integration Program at The Australian National University. Previously, Lachlan led the development of capabilities to monitor, optimise and control residential solar generation and battery storage, as well as developing virtual power plant technology to aggregate energy storage.

Marnie Shaw is a senior research fellow in the School of Engineering and a research leader in the Battery Storage and Grid Integration Program at the Australian National University. Marnie's current research interests lie in applying data analytics and machine learning to a range of data-rich problems, including the integration of renewable energy into the electricity grid.