Facilitating Community Understanding of Electricity Battery Options for Noosa Shire

Image modified without permission from Western Power installation in WA.

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Foreword

Zero Emissions Noosa Inc. is the community group working in partnership with The Noosa Shire Council (NSC) to achieve the common goal of ***Net Zero greenhouse gas emissions by 2026***.

This report has been prepared for Zero Emissions Noosa Incorporated (ZEN Inc.), working with representatives from the Coalition for Community Energy (C4CE), as an initial investigation of the issues and potential for a Battery Energy Storage System(s) located locally on the Energex network (Local Battery).

With high solar PV uptake and a power grid that was built for one way energy flow, ZEN Inc. has become aware of limitations on some businesses and households in the region to export any or some of the energy they generate but do not use locally. Moves are also being made at a national level to restrict the amount of solar generated by households that they can export to the grid, as a result of ageing energy infrastructure built for a one-way energy flow.

To investigate whether the energy generated locally can be used locally, and if using a local/community battery could be a solution for the Noosa region, ZEN Inc. has worked with representatives from the Coalition for Community Energy (C4CE) to learn more about how communities have and are using local/community batteries as a solution to storing energy generated locally, being used in the local area.

This report strengthens ZEN Inc's knowledge of the issues and solutions resulting from high levels of solar penetration in Noosa, strengthens ZEN Inc's capacity to inform and engage with the community about the emerging issues, potential solutions and next steps to achieve the Net Zero Emissions target by 2026 and assists to inform and strengthen ZEN Inc's strategic direction from 2021 – 2023.

I would like to take this opportunity to express my thanks to the members of the ZEN Working Group which led the project, and particularly to acknowledge Heather Smith, Vikki McLeod and Ewan Parsons for their thoroughness and technical expertise in reviewing the current local battery situation across Australia.

Anne Kennedy
President
Zero Emissions Noosa Inc.

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Purpose of Report

Zero Emissions Noosa Inc provided a terms of reference (appended) for this Local Battery report, stating the purpose of this work is to:

- Strengthen ZEN Inc's knowledge of the issues and solutions resulting from high levels of solar penetration in Noosa
- Strengthen ZEN Inc's capacity to inform and engage with the community about the emerging issues, potential solutions and next steps to achieve the Net Zero Emissions target by 2026.
- Inform and strengthen ZEN Inc's strategic direction from 2021 – 2023

ZEN Inc provided an information pack of relevant research for this work including:

A. Useful contacts
B. Relevant data
C. Presentations about ZEN Inc's work, including videos of EV expos

Executive Summary

This report has been prepared for Zero Emissions Noosa Incorporated (ZEN Inc.) as an initial investigation of the issues and potential for a Battery Energy Storage System(s) located locally on the Energex network (Local Battery).

The Noosa Shire Council (NSC) and Zero Emissions Noosa are working in partnership to achieve both organisations' targets of ***Net Zero greenhouse gas emissions by 2026***.

High solar PV uptake is driving the need for storage

With the natural advantage of a high level of solar resources, Australians have been investing in rooftop Solar PV in record levels. Regions in Australia with proactive local policies, like Noosa Council, have some of the highest levels of solar penetration in the world.

Of the 2.3 million customers in Queensland connected to the electricity grid, there are 700,000 customers with rooftop Solar PV systems and this number is projected to double by 2030.

In Noosa alone, there is 65 MW of Solar PV installed with 1MW being added per month. Energy Queensland is planning for 8.7GW of solar connected to the distribution networks, compared to a total summer peak of 8.2GW in demand by 2030. Some substations and distribution networks across Noosa Shire are already experiencing reverse power flows caused by moments of surplus solar.

This is both a challenge and an opportunity.

The challenge to change the electricity system

The speed and scale of Solar PV uptake is presenting risks to the electrical network as it is currently designed. The electricity industry across Australia is responding with strategies to redesign the networks and manage local supplies and loads.

Battery storage is one of the key strategies under investigation.

High levels of variable renewable energy generation are inevitable for Australia's energy future because our country is endowed with abundant wind and solar resources. As renewables increase, the electrical system will need higher levels of storage and from all sources (hydro, thermal and electrical battery storage). Storage allows for electricity to be stored at times of high generation such as in the middle of the day and be made available at times when the sun doesn't shine, and the wind doesn't blow.

The opportunity for Noosa Shire to benefit from its leadership

Local energy supplies bring local economic benefits. At current rates of uptake, high levels of locally generated rooftop solar energy will be part of Noosa Shire's energy future and key to reaching the zero emissions target. Leading the charge to tackle the network challenges and identify solutions that make the most of locally supplied solar energy, will also confer long term economic benefits on the Shire.

Over the past two years, numerous trials and studies of battery storage in Australia have been conducted demonstrating both the versatility, reliability and therefore the value of battery storage technology for electricity networks.

Battery energy storage systems (BESS) are still an emerging and relatively expensive storage technology. This report provides further detail on the various drivers of cost and value. As the cost of the technology drops, battery systems will grow in dominance and have a valuable role in electricity network management. Noosa Shire is well positioned to stay at the forefront of these developments.

Report Findings

This report provides a review of the more accessible insights from current Battery trial projects.

Our review of each project, trial or modelling report has focused on:

- Ownership models and business (implementation) models in use today
- Current and future value streams
- Emerging issues that may impact these value streams.

We have also reviewed the international literature on falling battery technology costs and the various value streams available to battery applications.

Our reviews are placed in the context of the Australian policy and regulatory environment which continues to change. Each change offers new opportunities for battery storage projects and new market entrants emerge as alternative revenue streams are developed within the electricity market.

Zone substation data for the six main substations in the Noosa shire provides the only comprehensive picture of peak loads, export levels and growth. A meeting with Energy Queensland supplemented these insights but ZEN Inc. will require further detail at the medium voltage feeder level and the low voltage level of the network if it is to identify valuable locations for local batteries.

The technical constraints on new solar installations are considerable with Energy Queensland reporting that new business installations are often given zero export limits. It is likely that these constraints are incentivising customers to install smaller systems or are acting as a disincentive leading to customers not installing solar at all.

This may change as Energy Queensland moves to using dynamic operating envelopes and to supporting dynamic load contracts. Dynamic limits will allow solar systems to operate without breaching the physical limits of distribution networks by varying the export limits imposed on each system by location and at different times of the day and year. This will act as a price signal and battery storage can be used to improve the use and value of solar production.

Our assessment of substation data shows that each zone substation sees low minimum load levels at times when the bulk of local power is provided directly by local solar energy. Several zone substations export local solar to the higher voltage system, particularly Cooran which exports on 121 days of the year. Electricity exports at the zone substation level indicates that many of the low voltage distribution feeders will be in export mode and many would be reaching capacity constraints or experiencing local voltage issues.

The following Local Battery solutions are all relevant to ZEN Inc. and each may remain relevant for Noosa Shire. Continued monitoring of costs and value streams will be needed before any single model becomes preferred for ZEN Inc efforts:

- Batteries that feed into the medium voltage system, co-located with business customers or electrical infrastructure and either behind or in front of the meter.
- Low voltage batteries that serve multiple customers on a low voltage feeder.

- Swap and Go battery solutions, integrated with electric vehicle services, noting that battery ownership, standard size and interface will limit such solutions to captive vehicle fleets.
- Support for multiple household and small customer batteries that are operated as a fleet in a virtual power plant arrangement.

Local Batteries are already achievable, without major changes to current regulations. Cost and the capture of value flows remain the main barriers to uptake.

Current capital costs for batteries in the 100kW to 1MW range produce a levelised cost of storage above 25c/kWh[1] over the lifetime of the asset. Smaller batteries are approximately 25% more expensive. Costs continue to fall, and the rapid expansion of the electrical vehicle market will help lithium ion technology, in particular, ramp up its experience, improve its performance and reduce its costs.

Local Batteries can have a positive business case if multiple values can be captured and 'stacked' to provide sufficient revenue. Some value streams such as backup capability or innovation benefits might be valued by non-market stakeholders like Noosa Shire Council and be the subject of an upfront grant (for example).

Electricity markets are evolving at a fast pace and there is substantial risk in assuming that today's value streams will endure for the 10-year life of a battery. The value streams described in this report are:

1. **Energy shifting** (daily storage behaviour) which could also produce value streams from:
    - demand management
    - freeing up capacity
    - deferred and avoided investment in network and centralised generation
    - local voltage support
2. **Responding to sudden changes in the supply / demand balance**. Unlocking commercial value would involve access to FCAS markets and the capability to bid appropriately.
3. **Power quality** – there may be local power quality benefits. The possible issues and the control arrangements to unlock benefits would need to be investigated further.
4. **Back up supply** to serve loads in emergencies and improve reliability
5. **Non-market (societal) value**.

These value streams are categorised in terms of the battery behavior and control that will produce the value. The sources of value are identified as electricity industry costs that will be offset, deferred or replaced when produced by a Local Battery.

One of the significant value streams for batteries could be reflected by local network pricing. Changes to network pricing have been mooted in the past and are being raised again by participants in trial battery programs. The pricing reflects the deferred or avoided investment in distribution networks that could occur if more electricity is traded locally. While local batteries will defer

[1] Levelised costs are explored in detail in section 4.2 of the report and reported costs vary widely from 14c up to 80c. Comparisons remain difficult as the battery application will affect lifetime and efficiency parameters. Stored energy starts becoming cost-effective if the input energy is free and energy use is worth more than 25c/kWh.

distribution system capacity upgrades, it is unclear whether Energex will develop methods to ensure the appropriate value can be captured by the batteries.

This report deliberately refers to Local Batteries and only uses the term Community Battery if the business model is designed to deliver community benefits. It is important to recognise that community benefit does not get unlocked unless there is a local entity to deliver combined with local leadership.

In its study on battery benefits (ANU, 2020a) expanded its technical analysis to delve into the social impacts and attitudes of customers. Its report emphasizes that fairness and equity; trust and transparency; hosting capacity; local resilience; and cost-effectiveness are all components to be deliberately designed into a community approach to local storage.

Yarra Energy Foundation (YEF) (Wallin, 2021) has also discovered that market models fail to deliver the desired community benefits. ANU and YEF are collaborating on a battery control system that can be adjusted to deliver more appropriate optimisation of community priorities.

Conclusions

The uptake of battery technologies in a range of applications is a rapidly moving proposition. Local Batteries are likely to be part of the future mix and can play a very important role in assisting Noosa Shire to reach its zero emissions target. The costs, network constraints and value flows will all play a role in determining the final applications that suit Noosa and it is important that ZEN Inc stay alert to opportunities as they emerge.

Battery trials suggest that early projects will need to be subsidised to proceed and a number of non-market benefits can be suggested to justify grant funding in support of a battery project. The learning associated with a battery that can reduce network constraints on the low voltage or medium voltage system will not come from the current Energy Queensland trials. Community benefits of improved electricity reliability, accommodating higher levels of solar on the network or local economic outcomes can all help justify a grant.

The business model, application and location of a Local Battery trial will all need further local and market information to be collected before the business case to proceed can be developed.

There is significant value in undertaking early trials in Local Batteries because the skills and knowledge produced for the region could be invaluable. Early insights will allow ZEN Inc. to better plan and prioritise a local storage strategy and subsequent roll out. **It is clear that the time to act is now.** The electricity market will deliver a suite of changes and government policy support is emerging in a variety of areas.

The following recommendations suggest strategies that, will maintain momentum for Noosa Shire, provide further information on which to base a business case, and ensure it keeps pace with the opportunities presented by a changing electricity market:

Recommendations

1. Continue to build constructive relationships with stakeholders such as Energex, Energy Queensland and the community.
2. Continue to pursue information and data collection, particularly to identify costs placed on Noosa customers by constraints, being mindful of the value of such data in the market place, and value to emerging commercial players such as an aggregator or Virtual Power Plant operator.

3. Develop a Lobbying strategy
    - Engage with Energy Qld and Energex as the local Distribution Network System Provider to understand local constraint issues, policy directions and operational opportunities for local batteries.
    - Promote the advantages of Noosa including ZEN Inc's work, community values and community engagement.
    - Highlight the benefits of the Western Australian Powerbank trial and other state initiatives to the Queensland Government (noting that Powerbank is aimed at the residential sector)
4. Open discussions with potential delivery partners and organisations with similar values and objectives such as Enova Energy, Power Club and Yarra Energy Foundation.
5. Consider the suitability of different business models including Microgrid, Aggregator, Virtual Power Plant as well as low voltage, medium voltage and business BESS applications.
6. Consider the benefits and risks associated with ZEN Inc. or Noosa Shire council becoming the local aggregator and VPP operator.
7. Investigate other delivery models used by Councils. For example, the energy service company model operating successfully in the UK and 51% owned by the local authority.
8. Develop a local register of Distributed Energy Resources (DER) with the view of supporting a future aggregator enterprise. DERs are controllable loads, solar PV systems, batteries and electric vehicles. This is independent of ZEN Inc. choosing to become an Aggregator but would be valuable market intelligence for an Aggregator[2].
9. Maintain a watching brief on the AEMO development of a DER register intended for the whole national electricity market[3].
10. Develop greater understanding of:
    - how a Local Battery is integrated into the Network
    - Electricity Supply Industry stakeholders and Energy Market Reforms
    - Limitations and the ability to address network issues.
    - The extent to which zero emissions will be supported by renewable energy within the Noosa Shire LGA and the possible need for future renewable imports. This informs the ambition for producing flexibility locally with battery storage.
11. Deliver a co-design workshop with key stakeholders such as Council and Energy Queensland to explore the project delivery options, engagement process, the role of Local Government, system design considerations and any other relevant issues.
12. Continue to scout for best locations for Local Battery systems. Locations with loads, space for solar and batteries and access to electrical infrastructure provide access to more value streams. Remote feeders and outlying communities are more likely to have constraints and to provide a higher value for improved reliability.
13. Investigate the suitability of areas with large roof spaces e.g. Shopping Centres such as Noosa Junction, Noosa Civic and industrial estates e.g. Noosaville and Cooroy Industrial Estates. Also a combination of businesses with large roof space and industrial sites e.g. Pomona in conjunction with local businesses from each area acting as an Industry Reference Group to ZEN Inc.. .
14. Further develop criteria around the location of a Local Battery such as the colocation with large electrical loads or locations with additional capacity for solar, transport or parking infrastructure including Swap and Go batteries

[2] In future there will be value in offering 1 sec monitoring and transparency to Energex from local solar and battery installations including electric vehicles, for example

[3] AEMO | Distributed Energy Resource Register

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Definitions

Arbitrage. Involves charging the battery when prices are low. This is likely to be during the day when local rooftop Solar PV generated electricity is abundant. Then discharge the battery when prices are high such as during the evening peak.

Behind the Meter. Generation equipment or energy technology assets that provide or use energy on-site without passing through the meter.

BESS. Acronym for Battery Energy Storage System.

Community Scale Battery has come to refer to a BESS located within the Distribution Network and 5MW in size or less (ANU, 2020a). Terms such as **Neighbourhood Battery** or **Network Battery** are also used. Hidden in the term are definitional issues about the ownership, purpose, voltage level and scale.

Control Philosophy. The control philosophy of a battery needs to be defined around the purpose and value streams the battery will serve. Batteries can be set to achieve market optimization, long life or emergency supply. The intent is designed into the control system via the algorithms that manage charging and discharging.

Control technology allows for the active control of the customers electricity demand profile - such as diverting solar output to battery and in response to a market price signal. This allows for the safe operation of the electricity grid by keeping the voltage within the technical limits of the electricity grid (substation, Medium and low Voltage feeders).

Distribution Network The electricity network typically consists of high, medium and low voltage grids. The high voltage is the transmission network transporting electricity between power stations to the population centres. The distribution network is the medium and low voltage grid transporting electricity to end customers.

Frequency Control Ancillary Services (FCAS) is an Ancillary Service traded in the National Electricity Market (NEM). If power generation rises, the frequency will rise. If electricity demand increases, frequency decreases. Therefore, demand and supply need to balance to keep the frequency as close to 50Hz as possible. There are two forms of FCAS - regulation and contingency.

FCAS Markets. It is AEMO's responsibility to manage frequency through the FCAS markets. If the frequency goes outside the Normal Operating Frequency Band (49.85Hz to 50.15Hz), the power system may result in a blackout. FCAS markets participants must be available to respond to a drop in system frequency within stated timeframes, and for this response to be sustained until frequency is restored to the normal operating range (usually within 10 minutes). There are eight contingency FCAS markets. Revenue is a combination of a capacity payment and FCAS payment.

FCAS Contingency Services (or system stabilisation services) is sourced at the plant equipment level and will respond to the frequency without a central command or instruction. There are six (6) distinct service requirements and market prices for each NEM Regions – they are Raise and Lower components across a fast (6 second), slow (60 second) and Delayed (5 minute) time frame.

FCAS Fast frequency response (or FFR) refers to an increase or decrease of power within a timeframe of 2 seconds or less. FFR is a crucial element to integrating higher levels of renewable energy. Noting Raise services are paid for by generators in the NEM, whereas customers/loads pay for Lower services.

FCAS Regulation Services (or load matching). A small adjustment of up or down (raise or lower) is sent from AEMO to enabled generators (and loads) to alter their output, thereby keeping the frequency at 50Hz. Too much generation for the given demand and frequency will rise.

Hosting Capacity is the amount of Solar PV that can be added to distribution system before control changes or system upgrades are required to safely and reliably integrate additional Solar PV. Although not a hard threshold, adding new Solar PV systems may ultimately trigger upgrades or changes to the electrical distribution system.

Local Battery. The terminology Local Battery is used throughout this report to refer to a BESS system connected to the Distribution Network.

Local Use of System (LUOS) charges. A discounted tariff by the Distribution Network Service Provider to reflect the limited use of the network system when energy is transported locally on the distribution grid and not through the transmission network.

Low Voltage is the voltage at which electricity is transported and delivered to customers and equipment. That is 415 Volts for 3 phase and 240 Volts single phase.

Microgrid. A microgrid is an electricity supply arrangement that can (but may not always) function autonomously and generates and supplies electricity to multiple customers. Within an existing electricity network, a microgrid needs to be able to disconnect from the main grid during faults (known as islanding) and continue to manage frequency and voltage by balancing supply with demand.

Medium Voltage is the voltage at which electricity is transported from the Zone Substations to the Distribution Transformer. That is 11kV and 33 kV (noting other states may use other voltage levels such as 22 kV).

Peak Demand Lopping. The battery can reduce peak demand charges by discharging at the highest demand intervals of each month. Peak Demand Lopping revenue can be either reduced demand charges for behind the meter configurations or value sharing with the DNSP.

Semi-Scheduled Generator. In the electricity market scheduled generators operate as instructed by the market operator and smaller non-scheduled generators operate without market constraints, eg a small solar system operates whenever the sun shines. The generation of semi-scheduled generators is forecast and the market operator may constrain the generation if necessary.

Virtual Power Plants (VPPs) is the aggregation and direct load control of multiple consumers' loads to derive local grid and market benefits. A number of VPP trials have been carried out, particularly in South Australia, aimed at controlling a fleet of batteries and at demonstrating the ability of a fleet to operate as effectively as larger single batteries.

Vehicle to Grid (V2G). Electric vehicles have batteries that can vary in size from 30kWh to well over 100kWh. Emerging as a technology, Vehicle to Grid (V2G) electrical design allows the vehicle battery to discharge and be usable as an energy generator when it is connected to the grid. Typical household batteries are 10kWh, so the capacity of an electric car battery is substantial.

V2L (Vehicle to load), **V2H (Vehicle to Home), V2B (vehicle to building)** and **V2X (vehicle to everything)** are also part of the electric vehicle lexicon. Definitions should distinguish between grid synchronized and off-grid applications (e.g. the battery drives standalone equipment like power tools) but the terms are often used ambiguously.

Virtual Cap Contract. A hedging strategy used by wholesale market spot price exposed customers. Cap contracts can be purchased to limit financial exposure to extreme prices (typically >$300/MWh). While not an exact replacement for a traditional financial cap, the battery is able to reduce risk of exposure 'virtually' in place of buying a cap contract by responding quickly to high price events.

1 Introduction

This report investigates local battery opportunities as follows

Chapter 2 explains community and local batteries in the context of the energy transition. It introduces the policy drivers for Battery systems and the benefits they can provide alongside general descriptions of the technology and Business Models.

Chapter 3 looks at the policy and regulatory context around Australia for battery energy storage systems (BESS). In particular, it draws out the policy settings for Local Batteries.

Chapter 4 identifies typical battery costs and develops an understanding of the various sources of value that need to be stacked to turn a battery investment into a commercial proposition. It explores the entities that tend to capture the benefits delivered by batteries and the regulatory and market settings that define how value can be captured by third parties.

Chapter 5 investigates the trials and reports from key initiatives around Australia. This chapter focuses on local batteries but also includes insights into the success of big batteries and relevant research that has been funded by ARENA.

Chapter 6 provides a snapshot of the electricity grid across six zone substations that supply electricity to residents of Noosa shire.

Our recommendations and conclusions are drawn together in Chapter 7.

The following drivers for investigating local batteries have been identified:

- 2026 zero emissions targets
- Barriers to reaching 100% renewable energy in electricity systems
- Opportunities for Noosa to maintain a leadership position
- The need to understand and anticipate emerging issues on the electricity grid
- Economic benefits that accrue from local electricity production
- Supporting the region to adjust during a rapid energy transition
- Developing an understanding of the different battery markets
- Identifying energy system reforms that will create new markets
- Learning from the many local battery trials underway around Australia

These drivers are summarised below.

ZEN Inc. and Noosa Council Aims

The Noosa Shire Council (NSC) and Zero Emissions Noosa Inc. are working in partnership to achieve the Council's target of ***Net Zero greenhouse emissions by 2026***.

Zero Emissions Noosa Inc (ZEN Inc.) have identified one of the key challenges in achieving the 100% Renewable Energy Plan for Noosa is the integration of higher levels of rooftop solar on the Energex electricity grid.

A local battery or batteries could be a solution to assist with grid stability and to allow electricity customers to export greater levels of solar electricity to the grid. ZEN Inc. are therefore seeking a greater understanding of Local Batteries.

ZEN Inc. has a further aim for Noosa to be the first trial Local Battery site in the Energex network service area.

Zero Emissions Noosa (ZEN Inc) maintains information on its website about the uptake of solar energy and has identified 1MW/year growth as shown in the graph below. In the year to June 2021 four of the local Zone Substations have had negative flows. On 244 days of the year Black Mountain has periods of operation at 100% renewable electricity. Cooran and Cooroy, similarly, sit at 242 and 178 days respectively with periods operating purely on rooftop solar. Even Tewantin exported surplus solar at sometime on 4 days of the year.

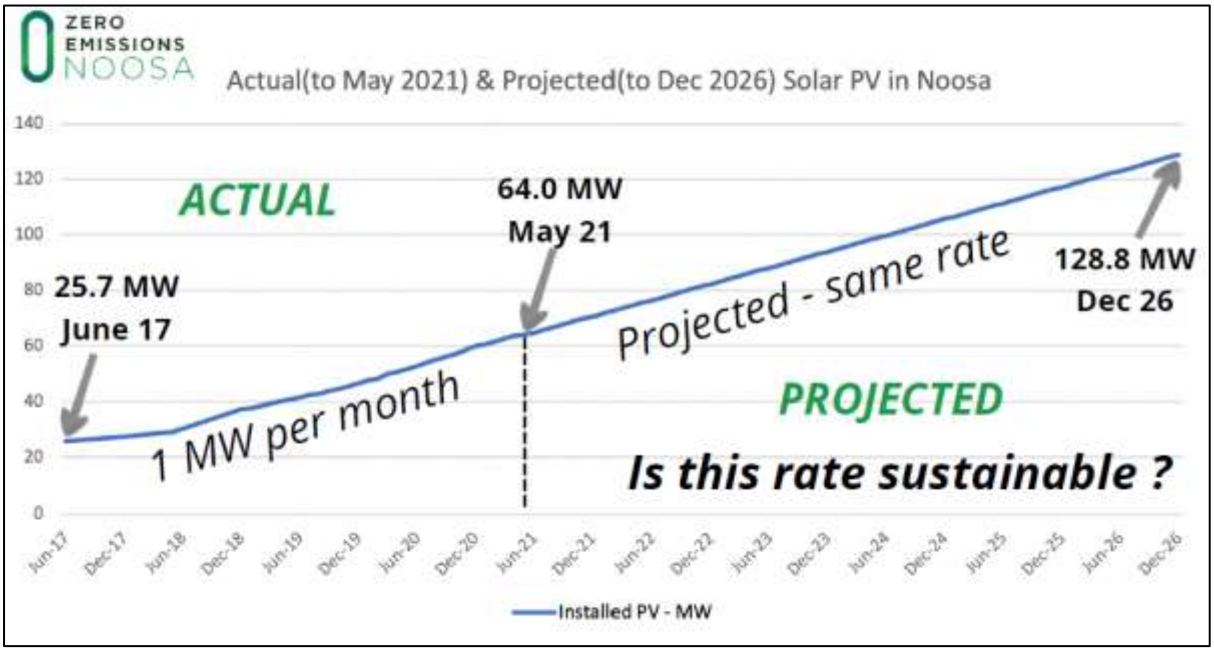


Figure 1 Projected Solar PV uptake for Noosa Shire (ZEN Inc.)

Zero Emissions Noosa (ZEN Inc) have identified that a key challenge in achieving the 100% Renewable Energy Plan[4] for Noosa is the integration of higher levels of rooftop solar on the Energex electricity grid. The 2018 report by ITP renewables focused on electricity but it is clear that reducing transport emissions, potentially via solar powered electric vehicle options, will contribute substantially to the zero emissions target.

Barriers to reaching 100% renewable energy target

The Noosa target of zero emissions is already threatened by local electricity constraints. Export limits on existing solar, dynamic operation of the network, extensive upgrade costs for new infrastructure, like electric vehicle charging, will all slow the pace of progress against the target.

Local battery solutions can resolve many constraints by storing surplus rooftop solar and deploying the stored energy when the demand for electricity is at its peak. Batteries are increasingly seen as a key technology for integrating 100% renewable energy into the Australian electricity system. The business case for batteries is improving every year as technology costs fall and technology performance improves.

[4] The 2018 report by ITP Renewables can be found at https://www.zeroemissionsnoosa.com.au/strategic-plan

Maintaining a leadership position

Noosa Shire LGA would benefit from early work to understand and trial battery opportunities.

Leadership on the issue would position the Noosa region to roll out multiple batteries as soon as the viability improves. Noosa has a climate aware and engaged community to support its leadership position.

The first regions to drive such investment will support their local businesses to design and produce the package of products which solve the integration-of-solar challenge. Even if much of the technology is developed globally, creating expertise to combine and install technologies is likely to confer local economic benefits.

Anticipating emerging issues

The capacity that is freed up by batteries, and can be used to install more solar, will need to be allocated fairly. Battery projects will trigger local conversations about shared energy assets. This opens the space for electric vehicles, shifting hot water loads and smart controls to also be discussed and understood more fully.

The design of a local battery will be influenced by opportunities to remedy grid issues in local areas, control other energy loads and emerging needs for vehicle charging. All these technologies will be used to achieve a zero emissions future and they impact fundamentally on social practices. Every community member needs to be given the opportunity to participate or provided with necessary support as the energy system changes these details of their lives.

Local batteries can make surplus solar more valuable and this will need to be communicated well so that decision makers understand how and why the market for export solar is changing.

Economic impacts

ZEN Inc. provide a substantial analysis of electricity consumption and costs at https://www.zeroemissionsnoosa.com.au/noosa-electricity-data.

Noosa Shire houses 56,000 people and 7,000 businesses. (Noting that this increases in peak holiday periods, with tourism being a key industry sector). Estimated expenditure on energy, based on a South Australian region that shares tourism, similar energy costs and similar solar penetration, is around $177m per year. The breakdown of this expenditure would be $50m for household electricity bills, $27m for business electricity bills and $100m for transport fuels.

Solar energy is already providing value to households and businesses of around $25m per year. This is the estimated reduction in electricity bills that has occurred due to investments in rooftop solar. The figure represents a capital investment that generates employment for local solar installers, who also maintain these systems over their lifetime. ZEN Inc also promote the benefits of energy efficiency which could be generating a further $3m-$5m in value for the region. For solar users who have paid off their investment, these savings are available to be spent in the local economy, so the benefit compounds in its economic flow on effect through the local economy. The benefit also increases over time. $25 - $30m is the cost saving on the original power bill, and further savings are achieved from not having to pay additional power costs as power prices increase.

An estimated $177m still leaves the region to pay mostly for fossil fuels. Achieving the zero emissions target will assist in capturing a major share of this expenditure for local benefits.

Australia’s rapid energy transition

Australia’s electricity sector is transitioning from centralised coal fired power stations to a 100% renewable energy future. Australia’s best renewable energy resources are variable and weather dependent - wind and solar. As a result, additional sources of storage will be required throughout the electricity system to maintain electricity supply at times when the wind doesn't blow and the sun doesn't shine.

Hydropower is Australia’s main source of energy storage today. New sources of storage will include Battery Energy Storage Systems (BESS) at varying scales and sizes. Unlike hydro storage or fossil fuel generation technologies, BESS can respond rapidly and provide electrical system flexibility to maintain grid stability. BESS are modular, providing much greater flexibility as they are easily able to be installed in local communities, in the best location and at the right scale.

The transition also demands a system where energy is no longer generated to match the load. Rather, the loads are moving to match the supply and using stored energy to achieve the supply demand balance. Smart hot water systems, electric vehicles and household batteries are all “loads” and forms of energy storage contributing to the energy transition.

Different battery markets

Big batteries or Utility-Scale Batteries are greater than 5MW in size and are connected to the transmission network. Most are commonly co-located with an existing generation source such as a Solar Farm, charging when there is an excess of generation and discharging when there is a deficit. A Utility-scale battery can act just like a large-scale power generator or a large variable load.

Community-scale Batteries are smaller in scale and between 30kW and 5MW. Community-scale batteries are connected to the Distribution Network, commonly located within our suburbs. They have the advantage of being able to provide local energy services to support the local network. As such, this report will refer to the Community-scale Battery as a Local Battery.

Utility-scale Batteries are a proven commercial proposition with over 300 MW already commissioned and connected to the transmission grid, another 500MW committed, and over 20,000MW in proposed projects.[5]

The main market to date for smaller batteries (e.g. less than 100kW) has been on the premises in households and businesses. Locating these batteries on the customer side of the electricity meter (known as ‘behind the meter’) ensures that customers see savings as reductions in their electricity bill. Combined with rooftop solar, small-scale batteries can provide backup power and maximise energy consumption from on-site Solar PV generation.

Energy system reforms create new markets

Many energy market reforms are proposed to better manage the rapidly changing energy system. 2021 expects to see 5-minute settlements and a Wholesale Demand Response Mechanism. A Two-sided Market by 2025 is an ambition of the Energy Security Board. ‘Two-sided’ refers to the idea that buyers and sellers in the electricity market are no longer single entities. Traditional electricity buyers can all become sellers of energy as well, leading to the emergence of the “prosumer”. As these reforms are implemented new market opportunities and new market actors will emerge.

[5] AEMO NEM forecasting and planning page

New actors in the form of aggregators will contract with multiple households and businesses to construct a fleet of assets from rooftop solar, small batteries and responsive loads, like hot water systems or pool pumps. Aggregators are already trading local battery power on the wholesale energy market. These are known as Virtual Power Plants (VPP’s). At the moment, electricity retailers such as Energy Locals are acting as aggregators but, in future, the Energy Security Board envisages many more third parties who can partner with retailers or access markets directly.

Vehicle to grid capability (V2G) where the battery in an electric vehicle, can become a storage battery and discharges useful energy to the grid, is attractive to aggregators. This technology and standard approaches are still being developed. Microgrids will also need to control multiple assets in the way that aggregators do.

A local battery can be dispatched in response to signals to alleviate local network and local generation constraints. BESS systems are well suited to these new markets due to the technology's versatility.

Local batteries at trial stage

Local batteries are emerging as a new business model but have not yet been demonstrated as fully commercial prospects. Western Australia started implementing batteries in 2018 and other states are rolling out their own trials this year. Local batteries can provide a range of energy and network services but are yet to reach their potential as not all services are currently valued.

As technology costs fall and electric vehicles become more commonplace, Lithium Ion batteries will become a dominant technology through BESS and Vehicle to Grid applications.

ZEN Inc has a further aim for Noosa to be the first trial Local Battery site in the Energex network service area.

A local battery would:

- Mitigate barriers to reaching the 100% Renewable energy and zero emissions target
- Help Noosa achieve a leadership position in striving for zero emissions
- Further encourage the uptake of solar
- Anticipate emerging issues from capacity constraints and the challenge of incorporating electric vehicles
- Offer economic benefits to Noosa shire

2 What is a Local Battery?

Large scale battery, behind the meter batteries, vehicle to grid are all Battery Electrical Energy Storage (BESS) systems and have the potential to play an integral role in Australia's transition to a decentralised grid.

The term Community Energy Battery has come to describe the benefit that can be gained when householders and businesses are granted access to a local distribution system battery.

Community Energy Batteries also referred to as “Community-Scale”, “Neighborhood Battery” and even “Grid Scale” Batteries, are connected directly to the electricity distribution network and “in front of the meter”. This report chooses the term Local Battery instead. We reserve the words “community” or “neighborhood” for battery installations with community benefits hard wired into the design and business model.

(ANU, 2020b) found that local batteries are already achievable without major technology developments and without major changes to current regulations.

Local Batteries are relatively new, the business model is still developing and depends on the ability to “value stack” multiple revenue streams.

However, some Local Battery models face regulatory barriers, and all models face logistic challenges.

The development of the various business models will be subject to incentives or price signals being created through changing policy settings, energy market rule changes and energy market reforms.

This section introduces the policy drivers for Battery systems and the benefits they can provide. It also introduces the markets for batteries in the context of a variety of energy storage technologies and business models.

2.1 Energy Transition, Decentralisation and Grid Transformation

In the last 12 months 4.5 GW[6] of Solar PV were installed in Australia[7]. Solar PV is now the biggest source of electricity generation in Australia. The uptake of rooftop Solar PV is occurring in Australia faster than any other country.

The electricity grid is transforming from a centralised system to a ‘highly’ decentralised system and characterised by the:

- Increase in generation connected to the distribution network
- Decreasing size of the average generator size (MW) capacity
- Increase in the number of active[8] participants with behind the meter assets such as Solar PV, smart appliances and, increasingly, BESS including electric vehicles.

[6] A GigaWatt (GW) is 1,000,000 kW.

[7] https://pv-map.apvi.org.au/analyses

[8] Where ‘active’ participants refer to the ability of Distributed Energy Resources (DER) such as an EV or battery, pool pumps or Electric Vehicle charging to be controlled and respond to market signals.

As we progress to ever increasing levels of weather dependent renewable energy generation sources connected to the electricity grid, this will present a number of problems for the management of the electricity grid.

The electricity grid was designed for:

1. Electricity to be generated at the transmission level rather than at the local distribution grid level.
2. For the supply and demand of electricity to be balanced almost instantaneously with supply following demand to match it accordingly.

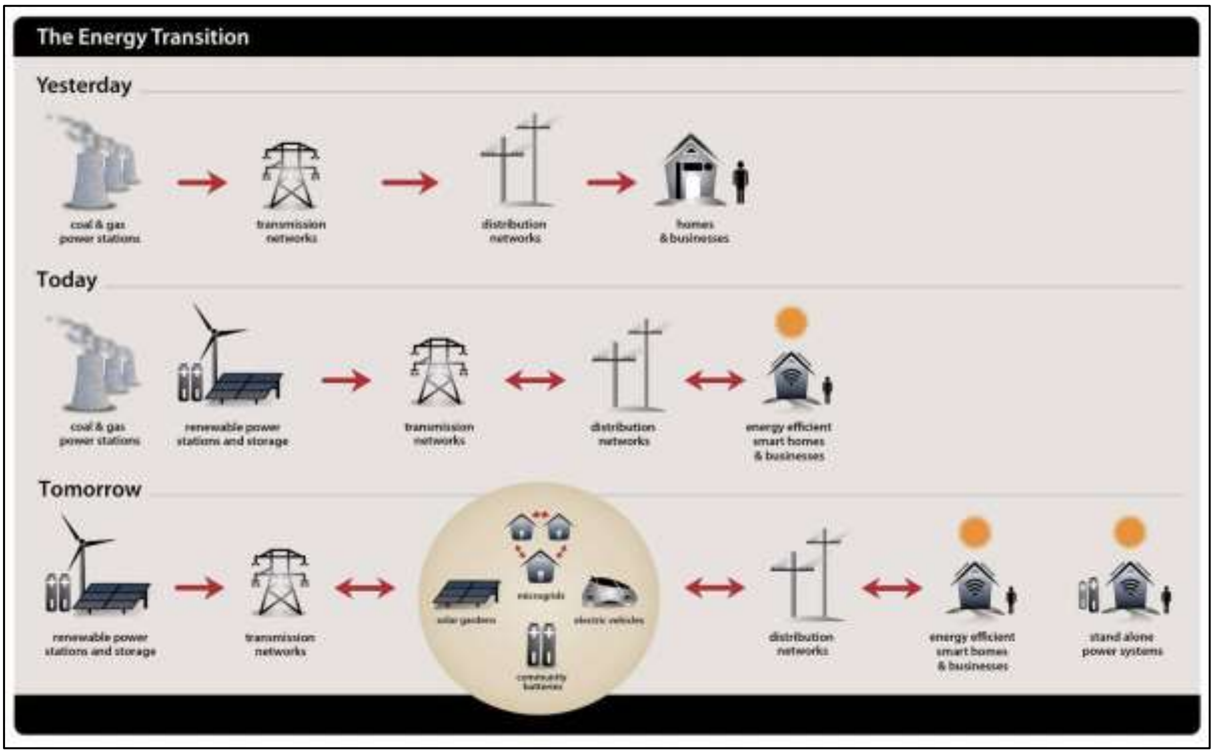


Figure 2 Electricity system transformation, (diagram source unknown)

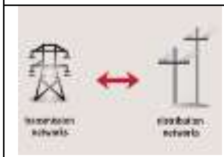
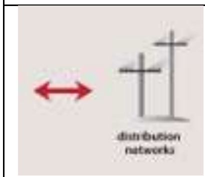
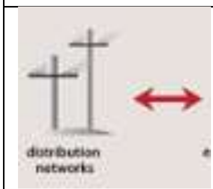
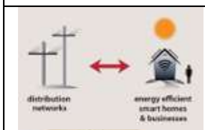
To maintain adequate grid stability and energy supply when the sun doesn't shine, and the wind doesn't blow - additional sources of system flexibility will be required and at every level of the electricity system. The transformation of the electricity grid to 100% renewable energy is often referred to as the “smart and flexible” grid.

Local batteries, along with household and utility scale storage, are an important part of the “smart and flexible” solution. Batteries can provide generation, as well as demand response, energy efficiency and real-time balancing across the whole energy value chain, right down to the household level.

Batteries will be a common technology in the new and emerging business models from Virtual Power Plants (VPPs), Local Energy Markets and micro-grids.

Battery applications, key features and labels across the future electricity grid take visual elements from the diagram above and are summarised in the table below.

Table 1 Comparison of battery and power quality contributions at different scales and voltages

Largest to Smallest	Possible Label And Scale	Voltage	Examples	Main value of example provided
	**Utility Batteries** 30MW – 500MW	Primarily located next to large generators where high voltage infrastructure is available	Hornsdale Power Reserve 100MW/129MWh	FCAS Use of surplus Hornsdale Wind (negatively priced or constrained)
	**Zone Substation Batteries** 1MW – 40MW	11kV or 33kV but feeding immediately through substation to higher voltages	Queensland battery trial 4MW/8MWh	Network support, delay of constraints and deferral of network investments
	**Medium Voltage (MV) Batteries** 100kW – 1MW	Feeding from behind or in front of a meter through a dedicated or customer transformer	Yackandandah Battery Trial at timber mill Any reasonable sized commercial customer has a dedicated MV feed.	Reduced energy bill by balancing onsite solar and load.
	**Low Voltage (LV) Batteries** 30kW – 500kW	Low Voltage 3 phase (415V)	Pole Mounted network battery Yarra Battery WA examples	Network support Use surplus solar Customer bill reductions
	Carefully located LV equipment (could be part of a battery project)	Low Voltage 3 phase (415V) and Single phase (240V)	Planet Ark static compensator Fast charging	Reactive power and voltage control Provision of large surges of power
	Virtual Power plants E.g. 20 x 10kW	20 - 100 households	Scattered on a single distribution transformer	Energy arbitrage Improved network capacity

	Household Batteries 3kW – 15kW	Single phase or three phase – depending on house supply	TESLA Powerwall SonnenBatterie	Reduced bills Overcome export limits Flat energy pricing
	Off-grid battery applications and emergency household supply 3kW – 15kW	Single phase or DC (Direct current)	Stand alone power systems Household batteries equipped with blackout capabilities	Full household supply, most of the year (often need a diesel battery in winter) Household bills plus reliability
	Electric Vehicles and mobile energy applications 15kW – 80kW	Can use both single phase charging (normal 10A or 15A socket) or 3 phase	One way charging electric vehicle Vehicle to grid capability through bi-directional charging and supply Swap n Go	Replace fuel bills with renewables …plus reduce energy bills Quick alternative to recharging

For the purpose of this report, local batteries are defined as those 30kW to 5MW battery applications on the Low and Medium voltage electricity networks.

2.2 The Role of Energy Storage Systems

There are a range of sophisticated, extremely well-designed Energy Storage Systems on the market, ranging in technology type, size, and cost.

The National Electricity Market requires a portfolio of energy storage to support system resilience by smoothing the operation of less flexible existing generation such as coal fired thermal power stations and the variable output of weather dependent renewable energy.

Energy Storage Systems includes a diverse range of technologies capable of varying response time, duration, and capacity.

Systems with six to eight hours storage potential are the most valuable in providing intra-day and day-ahead energy shifting. This size can complement generation from utility-scale solar and rooftop photovoltaic (PV) systems. Distributed storage (batteries) with shorter discharge times can provide value through capacity firming to support the grid at peak times.

- Pumped storage hydro which are suited for large capacity and longer-term storage.
- Thermal storage such as cold storage or air-conditioned voids such as shopping centers.
- Flow batteries, flywheels and hydrogen are emerging as options for longer-term storage
- Lithium-ion and Lead acid batteries are suited for the shorter-term storage.

Flow Batteries are a highly regarded but still an emerging technology. Flow Batteries are more environmentally friendly, safe, and able to maintain performance for up to 20 years.

The following diagram forecasts the role of different storage options to 2050. The study recognizes that different technologies perform differently in terms of duration, capacity, and cost[9] and therefore a range of investments will be made across electricity markets to adjust to renewable energy dominated electricity grids.

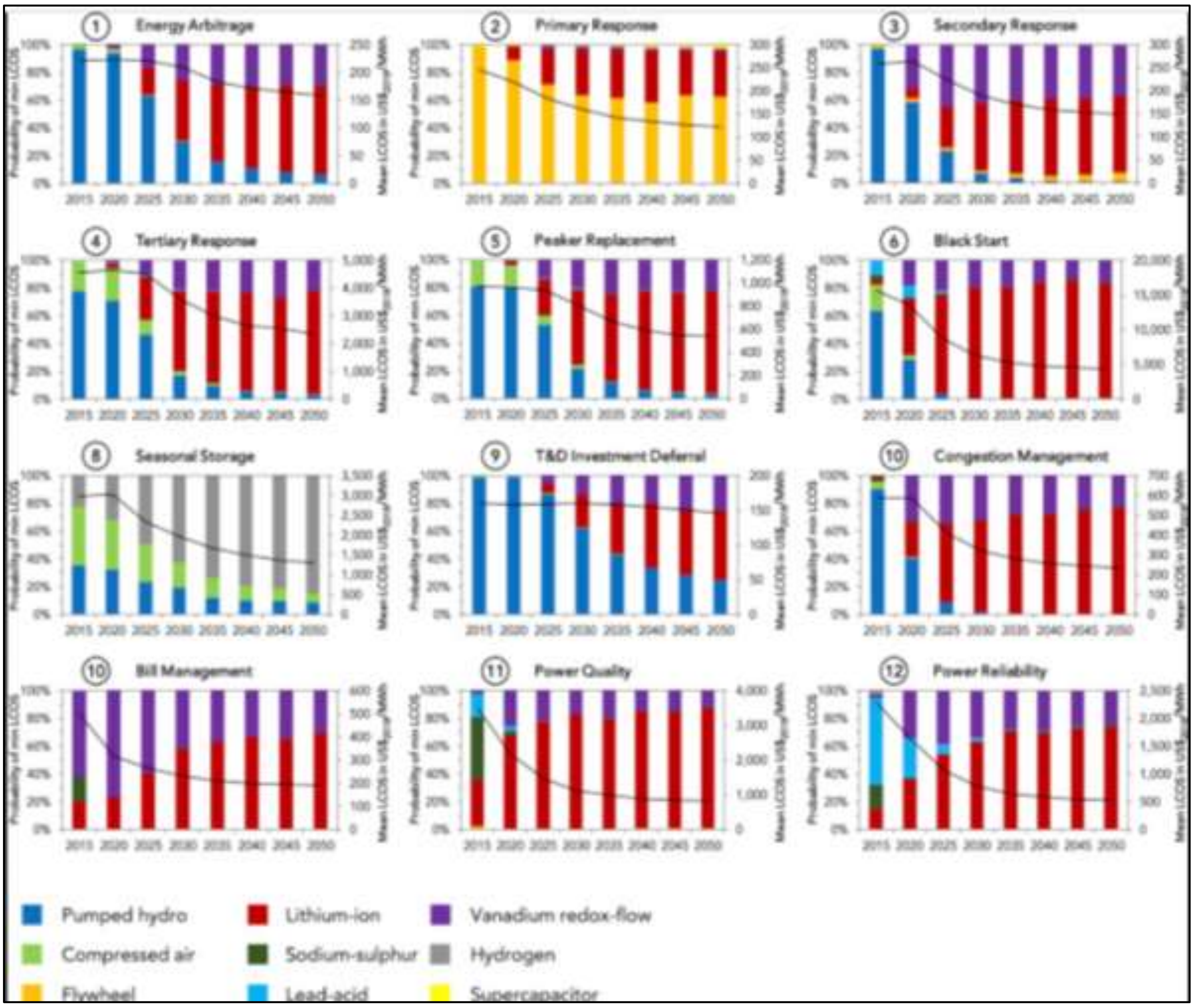


Figure 3 Twelve sources of value that storage can provide and likely technology suitability as costs fall (Schmidt et al, 2019)

BESS are rated by storage capacity, power rating and discharge rating and are sized to maximise returns for example 300MW / 600MWh indicates a power rating of 300 MW and with two hours storage.

In general terms BESS systems are flexible in size and can be designed for single or three phase voltages and can work in a range of grid support applications such as:

1. Household Systems: located behind the meter and coupled with Solar PV system and smart appliances to reduce electricity costs and peak energy demand.
2. Commercial & Industrial ESS
3. Vehicle to grid.

[9] Projecting the Future Levelized Cost of Electricity Storage Technologies by Schmidt et al

4. Community Energy Batteries: BESS systems that are connected to the electricity grid at the distribution network level and range in power capacity and size from 30 kilowatts (kW) to five megawatts (MW).
5. Remote Area Power Systems (Off Grid)
6. Community Electrification (Micro Grid)
7. Virtual Power Plants (VPP)
8. Network services (Grid Support Services)

2.3 Benefits at the Community-Scale

There is increasing excitement around Battery Energy Storage Systems (BESS) and the technology's ability to integrate higher levels of renewable energy particularly Solar PV into the grid.

As more electricity is generated from suburban roof top Solar PV than is being used, it is resulting in reverse power flow and causing technical problems for the management of the distribution grid.

Located locally and within the suburbs of our cities and towns, they are:

- Able to store electricity that is generated locally from rooftop Solar PV systems from households and businesses.
- Allow for the storage or "soaking up" the excess energy during the day and then make it available overnight and at peak demand times.
- Able to maintain power system security and prevent voltage issues when network daytime demand falls.
- are emerging as an important solution in Australia's Clean Energy Transition and Batteries

Local Batteries have a really important role to play technically, economically and socially in the transition to a low carbon future.

They can provide a range of network benefits, including:

- Manage the voltage, frequency, reverse power flow
- Mitigate minimum and/or peak demand within the technical limits of the electricity grid
- Balancing of electricity supply with demand
- Maintenance of stable frequency at 50 Hertz.
- Supporting the integration of more variable output Solar PV on the network
- Deferral or avoidance of expensive infrastructure upgrades

This is achieved by providing the services of:

- Charging and Discharging.
- On request or in response to a market signal.

The Battery Energy Storage System is dispatched in a similar manner as electricity generators have historically been dispatched.

2.4 Benefits of sharing the battery asset

Sharing a Battery Energy Storage System at the suburb or local level means an ability to expand the services and benefits of storage to more energy users, making more sense from a resource planning, economic perspective and social equity as:

- Individual batteries are not required at the household level.
- A local battery will require half the storage capacity compared to having individual batteries optimized to reduce household peaks for each household.
- It can support higher levels of renewable energy resulting in lower wholesale energy costs

Local batteries can increase the amount of distributed energy resources (e.g. solar panels and electric vehicles) that can be integrated into the distribution grid i.e. increase hosting capacity. This in turn allows for a greater uptake of rooftop solar PV, the orderly retirement of coal fired power stations and supports the yet to be electrified sectors such as Electric Vehicles.

2.5 Electric Vehicle to Grid

Electricity vehicle (EV) is a rising technology and eMobility a global megatrend. Some scenarios have estimated that in Australia it may grow the electrical load on the network by over 10% in the next decade. A recent ARENA report[10] highlights the barriers across both the transport and electricity sectors as electric vehicle designs and standards move from simple charging of electric vehicles to smart charging (V1G) and onto vehicle to grid (V2G) capability.

Like other BESS, Electricity vehicles (EV) store electrical energy through a charging cycle and discharge that energy to the wheels of the vehicle to provide eMobility. However, charging EVs, particularly through fast-charging stations, poses a significant challenge for electricity distribution networks. (For example, a Tesla supercharger needs 120kW of power and some rapid chargers draw up to 350kW. The capacity on the transformer to a street might only be 200kW.)

Distribution network challenges for fast charging could be alleviated if a local battery is also available to support the fast charging. Fast charging is often done using a DC (Direct Current) connection and a battery can supply DC energy directly to the vehicle.

If an electric vehicle has Vehicle to Grid (V2G) capability, it can be managed, to provide network support benefits and to respond to market price signals. Electric vehicles often have batteries that are significantly larger than household battery systems and exploiting this capacity is attractive to the electricity industry. Nevertheless, the ARENA report cautions that the business case for V2G may not emerge and recommends trials to further develop understanding of the opportunity. The automotive industry has been resistant to opportunities that could use the vehicle battery in unpredictable ways that could reduce the life of the battery or the performance of the vehicle.

Other V2 acronyms can be used in confusing ways. Vehicle to Load (V2L) has been used since the inception of electric vehicles to power modest loads. Vehicle to home (V2H) is generally presented as an off-grid technology where a home can be powered when it is not connected to the grid. Both of these applications require that the battery voltage is controlled which will match the amount of energy supplied by the battery to the load which has been attached.

[10] https://arena.gov.au/knowledge-bank/the-a-z-of-v2g/

Vehicle to Building (V2B) in the US appears to refer to commercial applications where vehicle batteries are used to reduce the electricity bills of the building, mainly through the management of peak demand. Like V2G applications there is no fixed load for the battery to supply so instead the battery current is controlled.

Vehicle to Everything (V2X) is the acronym being adopted to refer to battery control systems that can adapt to both off-grid and on-grid applications by controlling the voltage or the current as required. All applications where the battery in an electric vehicle is managed to provide electricity traditionally supplied by the electricity grid may be future value streams for an electric vehicle investment.

Increasingly, EVs are being built with this control functionality included and so the EV is enabled to discharge to the grid or to power the premises to increase customer resilience. The Vehicle Charging Management System (VCMS) is a central component of V2G along with the Integrated Charging Control Unit (ICCU) managing the vehicle charging functionality.

Ford has recently announced a pickup truck design able to power a typical home for up to three days and for use with power tools. Hyundai Ioniq has fully bi-directional technology in place for vehicle to grid (V2G) capabilities. Nissan Leaf and Mitsubishi Outlander should be available with bi-directional charger before end of the year. These examples demonstrate an automotive industry maneuvering to dominate in design and standards. Charging plugs, bi-directional capability and control systems all contribute to the emerging standards that are being agreed and developed. (see figure below)

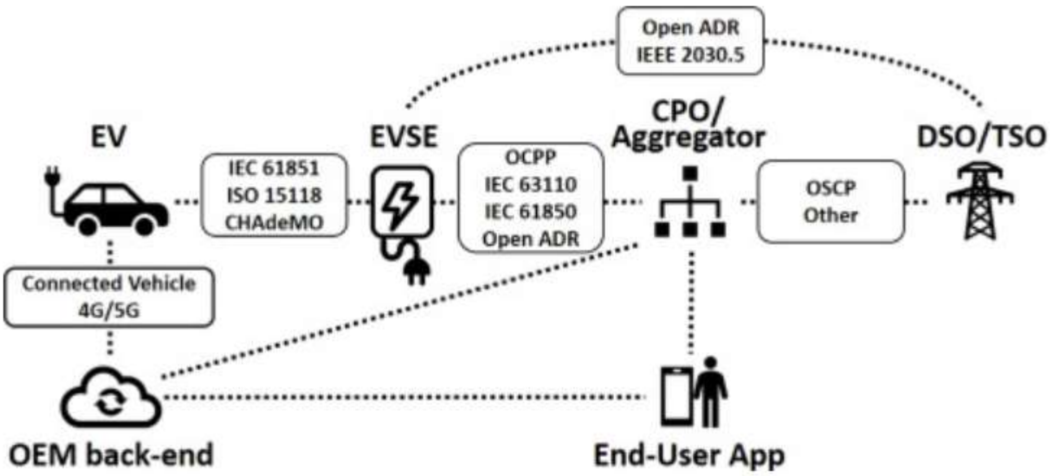


Figure 4 Main communications links and standards for flexibility services, (Gonzales et al, 2021)

In Europe alone, the eMobility market opportunity (EVs and infrastructure, Charge point equipment, Road and street charging, Roaming Smart charging) is projected to be significant growth sector over the next decade (Accenture, 2021). This value will be split between home charging and destination charging stations provided by business customers (e.g., hotels and supermarkets) and will take market share from petrol stations.

However, there is yet to be agreement on industry and International Standards for some pre-requisite technology such as adaptors and communication with the electricity grid.

According to EV and V2G Industry participants, this market will firm quickly, with the next 1 to 5 years being critical in defining market share and market development.

Assuming the pre-requisite technology, controls, standards, market, and policy settings can be addressed, the EV market may well come to dominate the storage market, either working alongside Local Batteries or displace market share from the Local Batteries. EV working as a Virtual Power Plant will be common to both scenarios.

Energex has recognised the implications for the electricity network through its Network Electric Vehicle Tactical Plan[11], as summarized by the diagram below:

Figure 5 Roadmap from Energex EV Tactical Plan

The recommendations in this report are aligned with many of the activities above.

[11] https://www.energex.com.au/home/control-your-energy/smarter-energy/electric-vehicles/our-ev-plan

3 Government Policy Support

There are still many questions around how greater levels of Solar PV can be integrated within the electricity grid and how this will be managed from a technical, economic, social equity and regulatory perspective.

A CSIRO study found that with a shift to local energy the resulting savings from avoided network investment and upgrades in that way the grid not only becomes cleaner but also cheaper (CSIRO & ENA, 2017).

This section looks at the policy settings and support for

- BESS systems in general and
- Local Batteries in particular

3.1 National Electricity Market Reforms

Since the Finkel Review (Finkel, 2017), there has been agreement that the Electricity Market needs reform to achieve the objective of:

- Integrating high levels of variable renewable energy generation particularly from weather dependent Solar PV and Wind.
- To allow the orderly exit of coal fired power stations.

To this objective, policy makers and energy market regulators are agreed on a package of reforms referred to as the Post 2025 Energy Market Reforms.

Currently subject to consultation by the Energy Security Board, these energy market reforms are designed to ensure ongoing reliability, security and affordability through Australia's Energy Transition (ESB, 2021).

Most relevant to Local Batteries business model is energy market reforms to progressively unlock the potential of the demand side and to compete in the wholesale market.

This will be achieved through Energy Market reforms such as Five-Minute Settlement, the Wholesale Demand Response Mechanism (WDRM), the Two-Sided Market and the introduction of new market participants such aggregators.

3.1.1 Wholesale Demand Response Mechanism

Commencing in Oct 2021, the Wholesale Demand Response Mechanism (WDRM) will allow for Demand Response to be traded on the wholesale market and with the effective of displacing coal fired electrical generation. The WDRM will also provide greater visibility and control of the electrical system.

Under the WDRM large consumers are able to sell demand response in the wholesale market, either directly or through specialist aggregators. This requires control system solutions to manage not only the battery, and offers potential for additional demand response initiatives, such as HVAC control, as they are developed. It also requires partnership with an Aggregator or other wholesale market participant such as a Retailer.

With the commencement of the market, it is expected that current and informal Demand Response contracts with large Industrial and Commercial customers will be formally traded on the wholesale market.

Transmission connected Big Battery technologies will be well suited to this market because of their fast response times and being able to provide energy shifting through charging and discharging, FCAS and Fast Frequency Response.

As the market matures, Aggregators and operators of Virtual Power Plants will aggregate smaller loads to a size able to be traded on the wholesale market that is 5MW and greater.

Trading on the WDRM will require a wholesale market trading license or a partnership with an electricity retailer.

The WDRM will see a permanent shift in the market, with new market entrants and clear price signals to shift load at peak demand times.

3.1.2 Two-Sided Market

The Two-Sided market (2SM) is a proposal to integrate variable renewable energy by creating an additional market at the Distribution Network level and post 2025.

Although subject to consultation and design discussion, the objective of the 2SM is to balance electrical generation with electrical demand to ensure the technical limits of the network are not exceeded.

This distribution network level market will trade in demand flexibility at the MV and LV and suburb level.

Each Local Energy Market will deliver local benefits such as maintaining system security and avoiding the need for expenditure to augment the Distribution grid.

Each Local Market Area will have Local Aggregators enlisting and (presumably) enabling customers to participate and (hopefully) creating an (fair) incentive for the customer to amend electrical generation and consumption patterns in response to a price signal.

Local Batteries with superior response and control ability will be well positioned to participate in a future 2SM.

3.1.3 Moving to a Distribution System Operator (DSO)

To support the Two-Sided Market (2SM) it is proposed that the role of the Distribution Network Service Providers (DNSPs) will change, and they will become Distribution System Operators (DSOs).

The proposed Distribution level market will be managed by a Distribution Market Operator (DMO).

The DNSP role is to transport electrons one-way from the transmission grid to the customers meter in a safe and reliable manner.

The role of a DSO will be to manage the transport of electrons bi-directionally and according to change in conditions such as Solar PV generation during the day or seasonally.

A DSO will be responsible for both transporting electricity and optimising for variable renewable energy generation, network capacity, network limits and other factors. All of this is made possible by increasingly active DER resources such as solar, batteries and electric vehicles.

The four basic functions of a DSO:

1. Providing a safe and reliable service in a dynamic System.
2. Giving customers options for how they use the network. Active prosumers may pay for higher levels of services compared to consumers that simply want safe and reliable electricity.
3. Using pricing as a tool to get more from the existing network. For example, dynamically signaling to electric vehicles when there is an abundance of solar energy in a neighborhood for them to charge from.
4. Supporting the overall system. By collaborating with the Australian Energy Market Operator (AEMO), DSOs will be able to align and interact with the wholesale market and the national electricity network.

While the details of the market are currently under consideration by policy makers, it is known that the future energy market will need to be more:

- Customer–focused
- Data driven

The key question will be if the market will be designed as what customers want or will it be what the incumbent energy participants want. Customers will want to maximise the benefits from their Solar PV, control their energy expenditure and take action on climate change.

While the DSO operating philosophy is yet to emerge, there are differences emerging between the states.

Energy Queensland is taking an approach of dynamic operating envelopes[12] rather than seeking to actively control DERs. In 2021 SA Power Networks started curtailing rooftop solar during infrequent network security events and it is yet to be seen if the Queensland government will follow this "smarter homes" initiative by South Australia.

3.2 Battery Policies by Jurisdiction

This section outlines policies and initiatives that may be relevant to local batteries and local energy markets.

3.2.1 Australian Government

The Australian government along with all state and Territory jurisdictions are participants in the "Energy National Cabinet Reform Committee" (ENCRC) and the "Energy Ministers' Meeting" (EMM).

Working closely with Energy Consumers Australia, the ENCRC have oversight key energy market reforms such as the:

- Energy Security Board (ESB)—whole of system oversight through transition

[12] Enabling Dynamic Customer Connections for DER | Talking Energy

- Australian Energy Market Commission (AEMC)—the rule maker and market development adviser.
- Australian Energy Market Operator (AEMO)—the system operator,
- Australian Energy Regulator (AER)—the economic regulator and rule enforcer
- Post 2025 Energy Market Reform package a

3.2.2 Federal Opposition Policy

Federal Opposition Labor Party announced a $200 million initiative[13] that would fund the installation of 400 local batteries across Australia and a tax incentive for Electric Vehicles[14].

3.2.3 ACT Government

ACT Government has a tender for a Big Battery and incentives for behind the meter investment for householders and businesses.

3.2.4 New South Wales Government

New South Wales remains behind states like South Australia and Victoria in terms of its renewable energy transition.

The Energy and Environment Minister Matt Kean has been providing leadership through ambitions like the Infrastructure Road Map. It includes plans to add 12 GW of renewables by 2030, resulting in big battery announcements and initiatives such as Ausgrid's local battery trials.

3.2.5 Northern Territory Government

The Northern Territory Government has:

- A 50 per cent renewable energy target by 2030.
- Battery rebate for eligible homeowners and businesses of $450 per kilowatt hour of useable battery system capacity, up to a maximum grant of $6,000.
- Tendered for a Big Battery to underpin the 400MW Darwin Katherine Integrated System. (The 35MW battery is expected to have a storage of around half an hour, meaning its principal role will be to provide essential grid services, such as frequency control, inertia and system strength, and step in to cover any impact of cloud cover on solar output, and reduce the need for gas-fired spinning reserve.)

The Northern Territory government anticipated the $30 million spend will have a five year pay back as a result of reduced gas costs.

3.2.6 Queensland Government

The Queensland Government has a 50% renewable energy target by 2030 with approximately 20% of electricity from renewable energy today.

In March 2021, the Queensland Government announced as part of a local battery trial plans to install five large-scale Community Batteries in Black River Substation Townsville, Tanby Substation

[13] $200 million Power To The People initiative

[14] Federal Labor promises to slash taxes for electric vehicles, build community batteries | RenewEconomy

Yeppoon, Bargara Substation Bundaberg, Torquay Substation Hervey Bay and Torrington Substation Toowoomba.

With a combined capacity of 40 MWh, State-owned Energy Queensland-owned sites have been identified for this trial. The batteries will be network-connected batteries and located in regional substations where deployment can occur as quickly and efficiently as possible, and where there is the highest penetration of solar on the network.

Energy Queensland already operates a network-connected 4 MW / 8 MWh Tesla battery at Bohle Plains in Townsville.

If successful, Energy Queensland could deploy distribution batteries in locations right across the state. The main driver for the trial at this stage appears to be an opportunity to develop experience within Energy Queensland in advance of 2030. Queensland has a 50% renewable electricity target by 2030 and modelling indicates that 8GWh of storage will be needed to accommodate this level of renewable generation in the electricity network.

3.2.7 South Australian Government

SA Power Networks has been grappling with high penetration of rooftop solar for some time and is generally seen as a leader in managing solar on the distribution network. Queensland also has high solar penetration but South Australia lacks the scale of Queensland's industrial loads and has already reached a day powered entirely by rooftop solar.

Since changing from a Labor state to a moderate Liberal state in 2018, the South Australian government has focused on individual household battery subsidies as its main strategy. It has attracted several battery manufacturers to set up operational capacity in South Australia.

South Australia was the first state with a virtual power plant (VPP) and battery owners can now choose between 10 different VPP schemes[15].

The Smarter Homes regulatory changes by the South Australian Government introduces technical standards for inverters and smart meters aimed at improving solar performance. It also includes tariff rules to ensure the solar sponge tariff is available to incentivize electricity consumers to use middle of the day surplus solar at cheap rates.

3.2.8 Tasmanian Government

Tasmania with over 90% of electricity generation from existing hydro is pursuing the "Battery of the Nation" plan which is to store renewable energy generation from mostly wind as pumped hydro.

3.2.9 Victorian Government

In March 2021, the Victorian Government announced a $3 million Neighborhood Battery Initiative[16] (NBI) to support battery trials and development. The objectives of the initiative are to:

- Facilitate and provide funding support for pilots, trials and demonstrations of a range of neighborhood scale battery ownership and operational models, including customer battery access services and innovative local energy trading models

[15] https://homebatteryscheme.sa.gov.au/join-a-vpp

[16] Neighbourhood Battery Initiative

- Address barriers to neighborhood scale battery deployment in the National Electricity Market (NEM) both in the short term to facilitate trials and through longer-term regulatory reform
- Engage effectively with customers and the broader community to ensure their perspectives are heard and considered as part of trial development
- Understand the impacts of different network tariff arrangements on the viability of customer retail storage models and battery operation; and
- Understand the viability and benefit flows for different ownership/operational models and ensure the community benefits of neighborhood scale batteries are maximised.

The NBI will provide 2 streams of funding[17] for project development and implementation including

- development of feasibility or business cases and technical, regulatory, legal and/or contractual advice to inform project planning and implementation; and
- demonstrate the ability to access multiple value streams

The NBI is part of a comprehensive Energy Transformation Strategy for Victoria[18] which outlines support for

- Energy Technology innovation
- Microgrid Demonstration Initiative
- Victorian Renewable Energy Target Auction Scheme
- New Energy Jobs Fund
- Energy Efficiency

Also of note is the Renewable Communities Program[19], a $1.139 million in grant funding aimed at community energy projects that will:

- increase the uptake of renewable energy generation;
- consider energy justice and social benefits;
- promote community participation and reduce greenhouse gas emissions.

The Renewable Communities Program is targeted fund, recognising the capacity and capability constraints often faced by community renewable energy groups.

3.2.10 Western Australia

Western Australia's electricity sector is experiencing a rapid transformation, with 30% of households with rooftop Solar PV and expecting to rise to 50% by 2030 and increasing the risk of blackouts.

Recognising they did not have the luxury of time, the McGowan Western Australian Government convened an Energy Transformation Taskforce and Strategy[20] which includes the following initiatives:

- **DER Roadmap**. The Distributed Energy Resources (DER) Roadmap, released in April 2020, is a five-year plan to guide the better integration of all distributed energy

[17] NBI - Application Guidelines - February 2021 (energy.vic.gov.au)
[18] Government-Links-October-2017.pdf (energy.vic.gov.au)
[19] Community energy
[20] Energy Transformation Strategy 2019-2021 (www.wa.gov.au)

resources, including solar panels, battery storage and electric vehicles, and ensure that the benefits are shared across all members of the community.

- **Future Battery Industry Strategy**[21] with the aims of developing a future battery industry through the support of Lithium mining, secure a role in global battery supply chains and create an investment environment for the uptake of batteries and electric vehicles in Australia and globally.
- **SWIS BIG Battery.** A 100 megawatt battery will be located at Synergy's Kwinana Power Station.
- **Clean Energy Project Fund.** A $66.3 million package for clean energy projects.

The WA Government is also supporting over 20 technology trials and pilots under way across metro and regional WA such as:

- Project Symphony
- Inverter upgrade trials
- Tariff pilots (x2)
- Stand Alone Power Systems (SPS) Regional microgrids.
- Schools Virtual Power Plants trial
- Smart Energy for Social Housing
- Electric vehicle charging infrastructure
- Western Power storage plan
- Community PowerBanks (x10)

[21] Western Australia's Future Battery Industry Strategy (www.wa.gov.au)

4 Introducing the Business Model and the Value Stack

Local battery business models, as for all business models, is an ability to capture value streams, identify and service customers' needs and to be competitive in the market.

In the case of Local batteries, the business model is emerging and in an environment of a fast moving and decentralising market.

Adding to this complexity, the business model needs to be understood from the perspective of who owns the Local battery, where it is located (in front or behind the meter), the customer base, to whom and how the revenue accrues.

Currently, there is no market that values the full range of services that storage can provide, making Local Batteries not currently financially viable.

However, there is consensus that batteries of all sizes will disrupt the National Energy Market including the frequency and ancillary services market.

This chapter is an examination of the key elements and commencing with understanding the value stack.

4.1 Battery Technology

In its most basic terms, a BESS has two modes of operation Charging or Discharging and an ability to "Value Stack" by providing a combination of distinct services.

Economic viability of Local battery Energy Storage Systems (C-BESS) will depend on maximising the revenue streams from these distinct services simultaneously.

The current economic opportunities for Local batteries and Battery Energy Storage Systems (BESS) more generally is an examination of the:

- Currently traded commodity including wholesale and local electricity market opportunities.
- Commodities to be traded in the future such as Demand Flexibility.
- Business model including customer base, key partnerships and technology innovation.

4.1.1 Physical Size of Battery Energy Storage Systems

A Battery Energy Storage System will range in size depending on the application.

A grid-scale battery or Big Battery such as Dalrymple North are connected to the transmission grid, servicing expansive areas of the electricity network and cover an area the size of 22 tennis courts.

A mid-scale Battery such as a 1 megawatt (1.07MW) Tesla Megapack battery with 2 megawatt hour (2.14MWh) of capacity, has a footprint of over 40 M^2 (around the size of a shipping container) and weighing 25.7 tonnes (excluding foundation). It is capable of powering approximately 115 homes each day, based on an average usage of 19kWh per household.

Smaller scaled Local Battery can be:

- Pad mounted
- Pole top mounted

And have a more compact footprint as shown in Figure 1

Figure 6 Pad and pole mounted Local Batteries

Smaller than local batteries are individual household batteries, such as the Tesla Powerwall.

Flow batteries are larger in size than Li-Ion batteries.

4.1.2 Degradation and Warranty

Based on a daily full cycle charge and discharge, a good quality Battery has a degradation of 2-3% per annum. However, there are some batteries that have much worse degradation.

As degradation factors into the revenue streams, it has implications to the Local Battery business model development.

Battery manufacturers may also factor degradation by oversizing a battery. For example, the rating may be one megawatt hour (1 MWh) with a 10 year warranty but may be constructed at a capacity rating of 1.4 megawatt hours.

Manufacturers may also leave physical space for the additional batteries for adding or replacing modules. Each manufacturer is working on improved battery chemistry and lifetime performance.

The less the BESS is cycled the longer the life of the battery life. A battery modestly cycled on a regular basis has the highest life expectancy but this may not produce the lowest levelised cost of storage. Shelf degradation effect means lifetime might be longer if the battery is stored at partial charge.

The balance becomes a question of operation and how value is extracted from the battery. This may manifest as cycling for shorter times, once a day or only at the opportunities to extract maximum value.

4.1.3 Pre-requisite Technologies

To be able to extract and realise value streams from the market, a Local Energy Battery System requires the following additional equipment and pre-requisite technologies to do so. Not all these technologies are currently commercially available.

1. AMI. Advanced Metering Infrastructure.
2. Control Systems. Involves Control equipment to protect the physical integrity of assets and maintain operation between technical rating of the assets. Also requires a control system strategy.

3. Communications. Effecting the control strategy requires communication with a Market trading platform. May also involve a field area network of communication if the trading strategies require active control of assets at the household or premises level.
4. Forecasting and Optimisation. Innovative commercial optimisation models inform trading strategy.

Local battery control systems and market trading platforms are emerging technologies and not yet commercially available.

There are companies providing a commercial service to inform and optimise operational performance. In time, Artificial Intelligence and other machine learning optimisation and market trading platforms will be developed and be commercially available.

While the technologies and the application of these technologies are yet to reach maturity, development is subject to international competition.

4.2 Capital Costs of Battery Systems

The business case for Battery Energy Systems depends not only on the capital cost, but also on the way the battery is used to produce energy.

Batteries combined with commercially and market focused optimisation strategies have the potential to unlock the full range of previously unvalued and untraded value streams.

The cost analysis below draws on:

- GenCost 2020-21, CSIRO for AEMO
- Ausgrid Local battery Feasibility Study report, KPMG
- IRENA energy storage costs report
- ARENA projects - costs of batteries from various studies

4.2.1 Levelised Cost of Storage (LCOS)

A strategy in the energy industry is to levelise the capital cost of equipment over the entire lifetime generation from that equipment and include running costs to produce a Levelised Cost of Energy (LCOE). Storage costs (LCOS) can be calculated in a similar way.

These parameters dominate the calculation of storage costs:

- Upfront capital costs – measured in dollars $
- Lifetime of battery which is impacted by how it is used
- Utilisation of battery measured in the volume of useful kWh discharged over the battery lifetime

A typical calculation, without financial discounting or performance degradation, is as follows:

- $1,000 / kWh capital cost for a 10kWh battery = $10,000
- Daily discharge = 10kWh/day x 365 days = 3,650 kWh/year
- 10 year lifetime = 36,500kWh / lifetime

LCOS ≈ $10,000/36,500 ≈ $0.27/kWh = 27c/kWh

To a lesser extent, operating costs, end of life (disposal) costs and degradation of performance over time affect storage costs and are considered when calculating LCOS rigorously.

Storage costs are added to the cost of the energy used to charge the battery and the round-trip efficiency (which is typically 90%), to obtain the total cost of energy produced by the battery.

The utilisation and battery strategy will affect the choice of battery type. Batteries are quoted in terms of capacity (kW) and energy (kWh) which quickly demonstrates how long a battery can discharge at full capacity. Household Lithium Ion batteries typically sell at 1-2hrs, so the Tesla Powerwall is 10kW/13.6kWh which equates to 1.3 discharge hours at 10kW capacity. Sonnen offer a 5kW/10kWh product (2hrs) and a 3.3kW/10kWh (3hrs) product[22].

Lazard[23] frequently provides industry metrics for new technology and is the basis for IRENA[24] reports. Lazard calculates LCOS costs for low and medium voltage (LV and MV) scale batteries as a range from US$ 590-247 per MWh which approximates to 90c/kWh down to 34c/kWh (AUD).

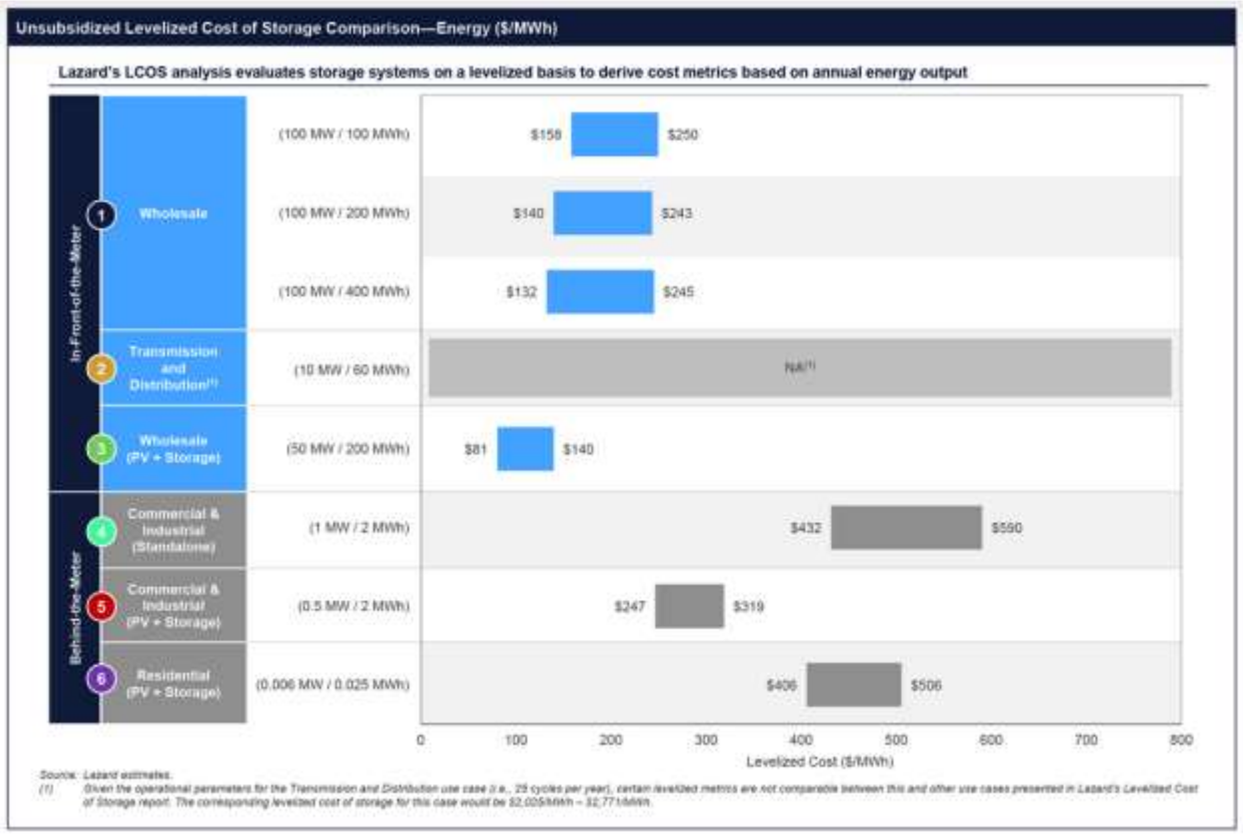


Figure 7 Lazard levelised cost of storage comparison

Lazard notes that prices are falling and this may explain why costs have remained stubbornly steady in Australia, albeit below the Lazard levels. Exchange rates and the dominance of the US Dollar in battery markets will also have reduced the ability of Australian prices to fall in line with US prices.

[22] https://www.solarchoice.net.au/blog/solar-pv-battery-storage-sizing-payback-calculator
[23] https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/
[24] International Renewable Energy Agency – Enabling Technologies: Innovation Landscape 2019

Australia was an attractive market for battery technologies in initial growth phases due to the high penetration of rooftop solar so global companies may have reduced commercial costs in order to establish businesses here.

Solar Choice[25] shows the battery price index for Australia and calculates LCOS for Household batteries. The metric is not comparable to Lazard as battery subsidies in various states are pushing household prices down and discounting methodologies vary. Solar Choice puts the LCOS cost range at 37c/kWh down to 26c/kWh although noting that this metric can be pushed as low as 14c/kWh if getting maximum cycles out of the battery within a shorter lifespan.

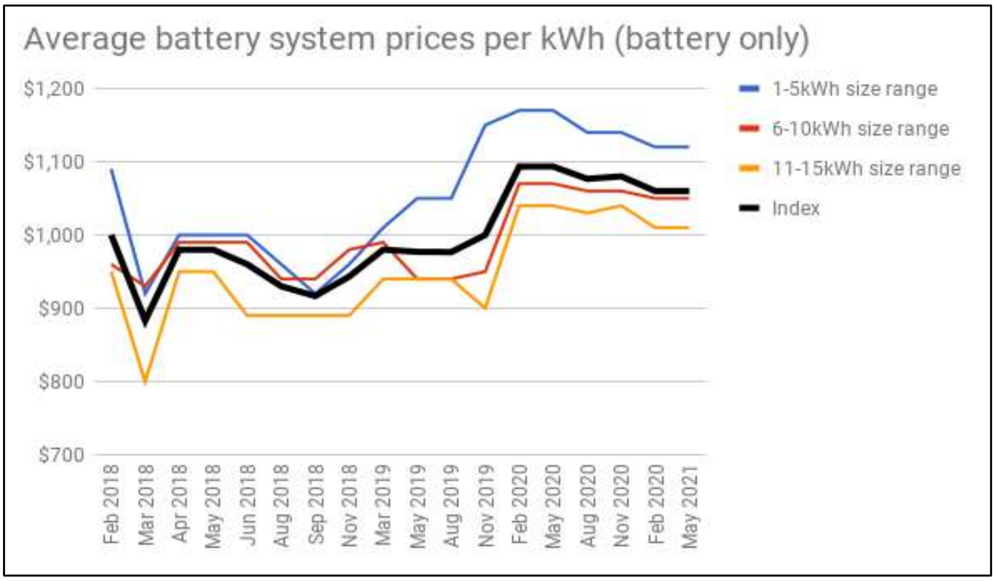


Figure 8 Solar Choice out of pocket battery costs

South Australian subsidies add $200/kWh to the battery price index for households (above) which reflects out of pocket costs. This puts LCOS for household batteries, without subsidies in the range of 40c/kWh down to 30c/kWh.

In comparison, the examples and studies chosen in this report are for batteries that are over 10 times larger than household batteries and have some economy of scale. The Ausgrid report highlights that these batteries also have greater costs for a container to house the battery and the additional control systems to operate it.

The clearest information comes from the University of Queensland who paid $954/kWh for 1.11MW/2.15MWh with the following breakdown.

[25] https://www.solarchoice.net.au/blog/battery-storage-price

Table 2.1: Breakdown of battery capital cost

	Cost (ex GST)	$ / kWh
Battery supply cost*	$1,700,000	$791
Battery balance-of-plant and Comissioning	$182,000	$84
Site Prep & Construction	$135,000	$63
Soft Costs	$35,000	$16
Total Cost	$2,052,000	$954

*Third-party supplier cost as part of EPC contract. AUD/USD foreign exchange rate was $1.40 in Dec 2018.

Figure 9 University of Queensland Breakdown of capital costs for battery project

A rough estimation of LCOS for the University of Queensland battery is 30c/kWh. (Some degradation of performance is assumed over the 10 year operating life). It is worth noting that UQ has not controlled the battery to deliver full discharge every day in the quarter showcased in the business case, but has exceeded its forecast revenue by selling into the FCAS markets.

Price Drivers

Prices are expected to fall, and battery performance is expected to improve over time. The "experience" that drives these improvements depends on large scale implementation of batteries globally.

CSIRO, for AEMO, recommend the following cost basis for capital cost of utility batteries with costs already 10-20% lower than one year ago.

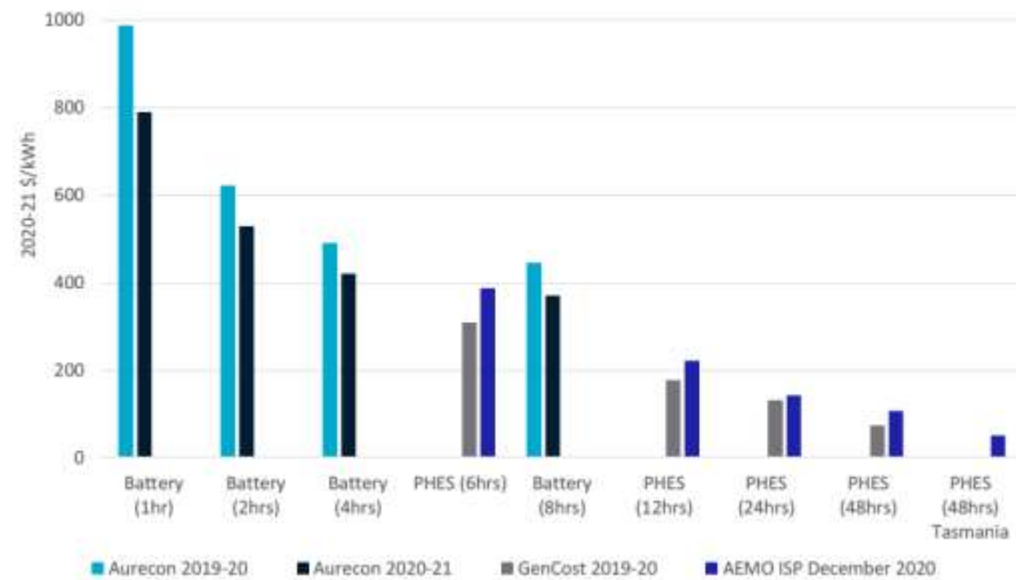


Figure 2-2 Capital costs of storage technologies in $/kWh (total cost basis)

Figure 10 Battery cost estimations of different expert sources

Tesla has stated ambitions to develop a 'million mile' battery for electric vehicles. This would provide around five times the current lifetime and drastically reduce the LCOS by offering far greater lifetime kWh.

4.2.2 Predicting the Declining cost of Batteries

Schmidt[26] uses the experience curve (used to predict the falling cost of new technologies), capital costs and utilisation metrics to project falling LCOS for Lithium Ion batteries (and other storage technologies). The average drops from US$350/MWh in 2020 to under US$200 in 2030. The cost range is consistent with Lazard and equates to around 46c/kWh in 2020 dropping to under 23c/kWh by 2030.

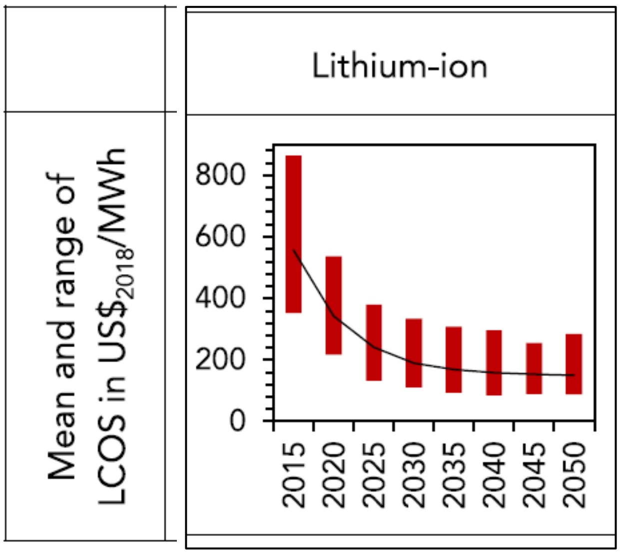


Figure 11 Projections for falling cost of Lithium Ion Batteries (Schmidt et al, 2019)

Utilisation has the strongest impact on LCOS results. A number of commentators point out that the correct sizing of batteries for the proposed usage is key to positive economics.

Schmidt compares 12 value streams for storage applications across 9 different technologies. A comparison of this nature relies on various assumptions but the results are worth noting for the ability to understand many different value streams and the ability to factor in the growing experience that Lithium Ion batteries will experience as the electric vehicle market explodes.

The graph below compares 2020 and 2040 showing that the market for Lithium Ion battery applications is expected to increase as it becomes the cheapest technology for providing longer discharges (1 hr extended to 8 hrs) and more discharges per year (beyond a daily discharge regime to 2-3 cycles per day). Note that flow batteries (purple) are not competitive in this analysis.

[26] Projecting the future levelised cost of electricity storage technologies (Schmidt et al, 2019)

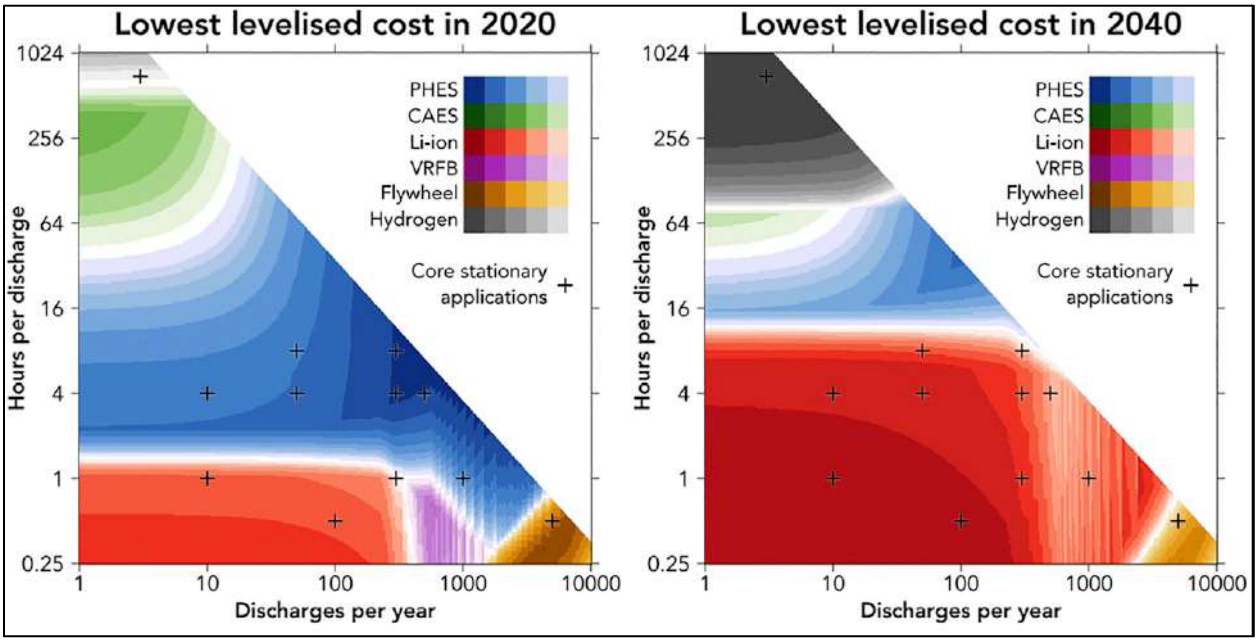


Figure 12 The projected growing dominance of Lithium Ion technology in red (Schmidt et al, 2019)

Yarra Energy Foundation (YEF) (Wallin, 2021) highlighted that a successful local battery would need an installed cost below a thousand dollars per kilowatt hour over the next few years. That equates to *installed* costs for a 250 kilowatt hour system of around $200,000. Installed costs include everything, not just the hardware. Costs charged by the network company (eg Energex) can be high for a local battery which has a relatively small cost compared to larger connections, making the Energex connection costs proportionally higher.

YEF also noted that battery costs are dropping about 15% a year.

The Vippy Modelling tool for battery systems has been developed by New Energy Ventures for commercial and industrial companies. Modelling indicates Victoria is one of the worst markets for commercial batteries, for a number of reasons including, low tariffs and volatility.

4.3 Battery Energy Storage Services

(ANU, 2020a) categorised five services that can generate revenue for the battery owner/operator:

1. Customer demand management.
2. Demand management for the distribution network service provider (DNSP),
3. Arbitrage from the wholesale spot market. A battery charges at times of low wholesale market price and discharges during times of high wholesale market price. the battery
4. Frequency and Ancillary markets (FCAS). To participate in ancillary services markets, a battery sells its capacity and or energy, typically into contingency FCAS markets. Local batteries would access such markets through retailers or aggregators because a minimum capacity is needed for licensing and system connection.
5. Service for TNSP and DNSP Network support. A battery provides demand response to a distribution or transmission network provider. The value is location dependent, however networks may run programs for easy access.

4.4 The Value Stack

Due to the high capital cost of Local Batteries, the business model development and the financial viability will depend on the ability of combining multiple value streams simultaneously and the concept of "value stacking".

The creation of new markets such as the Wholesale Demand Response Mechanism (WDRM) and the Two-sided Market (2SM) will only strengthen the business model for Local Community-Batteries.

Additional price signals could include:

1. Future Demand Response Participation.
2. Future Turn up services.
3. Future Network Management.
4. Future Virtual Power Plant.

4.4.1 Simple Value Stack

A Battery Energy Storage System (BESS) combined with a Solar PV system located behind the meter is an example of a simple value stack and business model[27]. The pre-requisite technologies and partnerships are grid connected, Existing retail electricity contract and Solar PV+BESS+AMI installed.

The following value streams accrue to the owner and network benefits are not valued:

1. Behind the meter optimisation. Maximise self-consumption from Solar PV generation.
2. Maximise Solar Self Storage by storing in battery for later use instead of exporting.
3. Arbitrage. A battery can optimise Time of use (ToU) tariffs by buying off peak and using during peak pricing or peak tariff.
4. Reduce Demand Charges. Discharge battery during times of high on-site demand and high retail prices.
5. Provide back-up power during black outs. (noting that significant additional investment would be required in islanding capability so the battery and loads can be disconnected from the grid and controlled in a suitable way to maintain power supply)
6. Avoided carbon emissions.

Although there are still barriers - such as information, search costs, upfront capital cost, split incentives - to unlocking this value stack, it is the simplest and easiest arrangement available to the householder and business to achieve.

This is the model used for example by Totally Renewable Energy Yackandandah.

The Business Model entity is also the customer. The economic opportunity is a return on investment of upfront capital cost of the assets.

Some value streams are explicitly priced. Other value streams are not priced but have value to the customer. For example, control over electricity prices, acting on climate change and certainty of supply.

[27] Solar And Battery Calculator: See Your Savings And Payback (solarquotes.com.au)

4.4.2 Advanced Value Stack

An advanced value stack typically involves market participation and/or need third parties to unlock the value stack. That is, the entity has exposure to the wholesale electricity market or has a partner with access the wholesale market such as a Retailer.

Value streams can be collated into distinct clusters that are delivered by particular behaviour of the battery. For example matching energy supply to energy load can save money based on the difference in cost between charging and discharging times (commonly known as energy arbitrage) and it can also save costs associated with peak demand or export constraints. The advantage of defining the value streams based on behaviour is that it identifies a source of value that is likely to endure, regardless of the many ways the market might choose to value it (or not).

Appendix D synthesises the value streams identified across 8 reports into the following clusters:

1. **Energy shifting** (daily storage behaviour) which could also produce value streams from:
   - demand management
   - freeing up capacity
   - deferred and avoided investment in network and centralised generation
   - local voltage support
2. **Responding to sudden changes in the supply / demand balanc**e. Unlocking commercial value would involve access to FCAS markets and the capability to bid appropriately.
3. **Power quality** – there may be local power quality benefits. The possible issues and the control arrangements to unlock benefits would need to be investigated further.
4. **Back up supply** to serve loads in emergencies and improve reliability
5. **Non-market (societal) value**.

The value generated accrues to different entities in different ways.

End users of electricity see direct benefits on their electricity bill if they 'capture' value. In an ideal market, end-users should see financial benefits whenever they generate value too. Instead, for some activities the benefits will be spread across all customers and in some cases the benefits will not be immediate, so future customers will be the beneficiaries.

Network businesses like Energex will benefit whenever and only if investment is deferred or avoided. When outages exceed set limits this also triggers investments because network businesses like Energex are expected to reach agreed performance targets of both the frequency and duration of outages. A poorly performing part of the network will normally become high priority for replacement or upgrade.

Network costs are defined through a regulatory process because networks are a monopoly. They make up roughly half a customer bill and frequently do not reflect the cost of serving individual customers because networks (poles and wires) are essentially shared assets. In the long term, cost reductions can be expected if the existing network assets work harder. This will be the case if local solar can be guaranteed to service local capacity and if new electric vehicle loads use existing capacity rather than demanding new build of network capacity.

Large generators compete in the wholesale market. This means much of the savings from reducing the need for wholesale market generation can be passed on the end customers.

Further work on the value stack will help identify which entities capture the value from Local Batteries and opportunities for the battery to be fairly rewarded. Some insights into wholesale markets and tariff arrangements are detailed below to commence this work.

4.4.3 Market and Response Criteria

There are strict market criteria for unlocking wholesale market value streams. Criteria such as response time, reliability of response, duration of response and depth of response.

VPP battery and 2-hour large-scale batteries are more suited for capacity, fast ramping, and FCAS than they are for value generation from energy storage.

The value of Medium storage (4-hour batteries, 6-12 hour pumped hydro) is in its intra-day shifting capability, driven by demand and solar cycles.

The value of Deep storage (24-48 hour pumped hydro) is in covering long periods of lower-than-expected variable Renewable Energy availability such as drought and seasonal smoothing of energy over weeks or months.

On 21 July 2021, the rules around Fast Frequency Response were rewritten causing some controversy[28].

4.4.4 Challenges

As outlined in the Q1 performance of University of Queensland's 1.1MW Tesla behind-the-meter battery (Wilson, Esterhuysen, & Hains, 2020) despite being successful overall, a number of key issues and learnings emerged such as:

1. Challenges of Developing an Effective Control Strategy to maximise arbitrage revenue.
2. Unreliable AEMO pre-dispatch price forecasts.
3. Deciding on an arbitrage strategy with price certainty in the moment ("one in the hand") versus the potential for higher - but more uncertain - returns later ("two in the bush").
4. '5/30 rule' whereby spot prices are set every 5 minutes but financially settled based on a half hourly average.
5. Nuisance Tripping. The battery also spent a cumulative total of 124.5 hours (5.7%) of the quarter offline. This was primarily a result of nuisance tripping related to electrical protection settings that have since been tuned to avoid the issue.
6. Physical faults with one out of 10 of the battery packs.
7. Network Outages impacting the control system architecture, causing the battery to revert to outdated charge/discharge patterns or requiring manual intervention.

4.4.5 Tariff Structures

Tariffs across the NEM differ. Queensland and South Australia tend to have higher costs and this can benefit the business case for BESS systems. The tariff that a household or business pays can be disaggregated to demonstrate the contribution toward:

- Distribution costs – low voltage

[28] Did AEMO just kill off the market for battery-based Virtual Power Plants? | RenewEconomy

- Distribution costs – medium voltage
- Distribution costs for backbone
- Transmission costs
- Generation costs
- Retail costs
- Other charges such as environmental

This is recommended as a future piece of work. The value that the local battery generates is some proportion of the cost in each part of the stack and will reflect the extent to which the local group of customers no longer need that service from the traditional market.

4.5 Discussion

ARENA funded the Australian National University (ANU) through their Battery Storage and Grid Integration Program to do a significant study (ANU, 2020a) (ANU, 2020b, 2021) on the potential for local battery models to be deployed throughout Australia.

The key lesson from this project was that local batteries are already achievable, without major changes to current regulations.

The key challenges for the implementation of local storage are:

- How to manage service contracts to multiple parties e.g. retailers and DNSPs.
- How to balance the provision of services, to benefit all stakeholders e.g. energy users and the network.
- How best can DNSPs procure the services that storage can provide, from storage owners within the current framework.

The findings and key lessons learned were:

- Communities like the idea that the electricity generated from their rooftop Solar PV system is going to be used locally.
- The technical capability for implementing local storage on the NEM already exists.
- Reduced local network tariffs are crucial for incentivising battery charging from locally generated solar energy and sale of energy to local customers.
- Network tariffs and market signals shape how the battery's actions contribute to hosting capacity.
- Local batteries can be economically beneficial, particularly if FCAS markets can be accessed. (as per below, new tariffs would be required to unlock some of the economic value)
- The technical capability for implementing community-scale storage on the NEM already exists.
- Only DNSP-owned local batteries currently require regulatory exemptions (and only if the battery is being used for anything other than regulatory network services). All other models we investigated can proceed within the current rules and regulations.
- Reduced local network tariffs are crucial for incentivising battery charging from locally generated solar energy and sale of energy to local customers.

- Industry professionals saw significant potential benefits of local batteries, including over behind the-meter (BTM), virtual power plant (VPP) storage. They also consider the dynamics between actors in disaggregated markets to be a major challenge [2].
- Householders care about more than just affordability when it comes to energy storage e.g. strong concern over battery life-cycle, promoting local energy use, reducing carbon emissions, questions of fairness and how this technology would fit in the broader energy transition to renewables [2].

The full suite of reports from the research can be found at the ARENA website: [Community Models for Deploying and Operating DER - Australian Renewable Energy Agency (ARENA)]

The Local Battery solution presents a complex array of challenges and involves changes at the technical, policy and regulatory level.

Energy policy makers and regulators are currently discussing these issues nationally and considering electricity market reforms to enable electricity generated locally to be bought, sold and traded.

The (ANU, 2021) study found:

- The financial viability of almost all community scale storage projects will require a discounted local network tariff (LUoS)
- A reduced energy transport network cost for ‘local use of service’ (LUoS) is required to financially motivate charging the battery with locally generated solar energy.
- Distribution Network Service Providers (DNSPs) can own a battery but cannot use that battery to provide contestable services, unless a regulatory exemption is given. However, DNSPs can procure network services e.g. voltage and demand management, from third-party operators within the current framework.
- Third party owned local battery models can be financially viable, under current energy and FCAS market prices. To ensure the future economic viability of these models, payments for the network services they provide need to be established.
- A DNSP (or network operator) owned local battery is unlikely to be financially viable without adding a significant proportion of the battery cost to their Revenue Asset Base (RAB).
- A DNSP owned, for-profit battery, could potentially be financially viable under current market conditions, if a significant proportion of the battery was leased to another party for market participation.
- Distribution Network Service Provider (DNSP) owned battery trials will require an exemption to current rules in order to use the battery for anything other than regulated network services,
- Our investigations have shown that — overwhelmingly — these trials and demonstrations can proceed within current rules and regulations.

5 Review - Australian Battery Projects, Pilots and Trials

This section reviews the Australian Battery projects, pilots and trials that are relevant to Zero Emissions Noosa Inc's Terms of Reference with greater focus on Energy Queensland's battery trials, and including ARENA local battery studies

A summary of Transmission connected Batteries and DER trials (ESB, 2020) is included.

The discussion of each project helps identify the business model elements so to enable the understanding of the different ownership models. The value captured in each model varies. Value in the network benefits through Grid support; Voltage support; Network Constraint management and support local peak summer demand driven by air-conditioning have all been identified at times.

The aim is to introduce and explore elements that ultimately affect the business model including but not limited to: Commercial Models, Key activities, Customer Segments, Customer Relationships, Pursuit Strategy. Customer Channels, Competitive Advantage, Policy Requirements, Regulation and Planning.

5.1 Distribution Grid Connected Storage

Local Batteries connected to the Distribution Network and located within the suburbs are becoming more common around Australia.

Distribution Network Service Providers (DNSP) are realising the network service benefits of time shifting Solar PV generation to stabilise ageing and increasingly constrained Low Voltage and Medium Voltage grids.

Western Australia is leading the way on a shared storage business model and the PowerBank trials stage 1 though to 3.

This section discusses the differences between ownership models and also location.

This section also lists pilots, trials and commercial Local Battery projects sized between 100 kW and 5MW.

5.1.1 Battery Ownership

The position of the battery owner within the energy market and therefore the business model is an important consideration for the potential future rollout of local batteries.

There are three ownership / business models for a Local Battery based on ownership by the:

1. **Electricity Retailer**.
   Retailers are well positioned to access market services and engage customers with on-bill participation models such as tariffs and subscriptions.
2. **Third-party.**
   Third party owners could include private investors, community groups, and local or state governments, or a combination of these groups.
   The structure could be either "For Profit" or "Not for Profit" with the community as the beneficiary.

3. **Distribution Network Service Provider**.
   As owners and operators of the distribution network DNSPs have visibility of and understanding of where the network services and augmentation is required.

The ownership of the large-scale battery by a cooperative or collective could genuinely be called a Community Battery if operating for the benefit of community. It would be one of the third-party ownership models.

Common ownership structures are as follows:

1. Community Group. For example Community Energy 4 Goulburn Solar Farm and battery
2. Community Retailer. Such as Enova Energy The Beehive shared community Battery.
3. Retailer. Such as Synergy's Alkimos Beach (WA) community energy storage device.
4. Distribution Network Service Provider. United Energy's bayside pole mounted battery systems.
5. Third party. Such as Yarra Energy Foundation's Melbourne Solar Sponge in collaboration with Citipower.

For each ownership / business model the customers, benefits, costs and the value streams they capture will differ.

Retailers as owners raise problems of network impacts and of fairness and transparency. (ANU, 2020a) found members of the public were wary of retailers' profit motive and the opaqueness of tariffs and bills. Retailers may not be well positioned to access non-market services such as network support. To receive payment for these services they would need to establish a bilateral agreement with the DNSP.

DNSPs are regulated and with BESS systems within their network and are well positioned to maximise the value capture. (ANU, 2020a). The vertical disaggregation of the NEM prohibits DNSPs from providing market services or owning an asset that is used to provide market services. Although some conditions allow this to occur, they require permission from the Australian Energy Regulator (AER) on a case-by case basis. A situation that is particularly beneficial for equity and hosting capacity goals and is currently allowed in the regulations is for networks to deploy local batteries in situations where they are a cost-effective solution for network services. In these cases, the network receives a return on investment through network charges and — in an ideal world — the net benefits are shared amongst their customers through lower future cost of providing services.

5.1.2 Location - Behind (BtM) or Front of Meter (FoM)

A Battery System located behind the meter, will allow the owner to extract value exclusively by providing services from "behind the meter" (BtM).

A BtM battery system may also be market facing providing network-initiated services. This will be commonly part of a Virtual power Plant or in the case of University of Queensland which has exposure to the wholesale market.

If the Local Battery is located in front of the meter, it is able to access additional value streams.

Depending on the network issues and local constraint conditions, the Local battery may be connected to either low voltage or medium voltage. The local conditions may include major network constraints, or a large load centre, restricted hosting capacity or network upgrade required.

It is more likely that the main voltage issues are down at the low voltage level and not so much at the high voltage level.

There is also a social dimension in that if the Local battery is located in the neighbourhood, people see it as their neighbourhood battery.

5.1.3 Pilots, trials and commercial Local Battery projects

The following table outlines a selection of Distribution grid connected Local Batteries sized between 100 kW and 5MW and detail on the technology, costs and value capture where available.

Table 2 Summary of local battery pilots and trials

Project	Technology and Costs	Value Capture
NSW, Bankstown Beacon Hill Ausgrid	Costing $400k	DNSP Owned Relieve hosting capacity constraints. Virtual sharing vs VPP
NSW, The Beehive Project, Hunter Valley Enova Energy	1.07MW/2.14MWh Tesla Megapack battery	Front of meter. Retailer owned Market Facing
QLD, University of Queensland	1.1MW / 2.15MWh Tesla Powerpack Costing in all $2.05 million ($954/kWh) Commissioned NOV 2019	Privately Owned. Behind the Meter. Market Facing Revenue from Arbitrage; FCAS; Virtual Cap Contract; RE+BESS+Future Demand Response
VIC, Bayside Battery Project, Highett United Energy	Trial of 2 x Pole-mounted batteries costing $500,000	DNSP owned LV network Improved network reliability
VIC Community Battery roll out for SE MLB suburb[29] United Energy	40 x 1.2MW/2.7MWh Pole-mounted batteries as part of $11 million project	DNSP owned LV network Improved network reliability where the LV network is constrained
VIC, Mallacoota Area Grid Storage (MAGS), AusNet Services	1MWh BESS Lithium Ion $2.5 Million Commissioned MAY 2021	DNSP owned Backup power during planned and unplanned outages and faults. DNSP avoids reliability penalty payments with expected reliability improvements of 90%.

[29] United Energy reveals community battery rollout for suburban network – pv magazine Australia (pv-magazine-australia.com)

VIC Power Melbourne Melbourne City Council[30]	Capacity of 5 MW by 2024 Located on MCC sites as a network of co-ordinated community batteries $300,000 allocated for pilot	Council owned Aim of the scheme is to deliver more renewable energy into the grid, accelerating the City of Melbourne's ambition of being 100% powered by renewable energy by 2030.
VIC Melbourne Solar Sponge[31] Yarra Energy Foundation	Tbc	Front of meter. Third party Owned LUOS from Citipower Co-investment model with householders
WA, PowerBank 1 Meadow Springs, Mandurah, MAY 2018 Synergy and Western Power	105 kW/420 kWh Tesla Battery	DNSP owned, Retailer operated. Virtual sharing Deferment of Network Augmentation
WA, PowerBank 1 Ellenbrook, Perth Falcon, Mandurah, NOV 2019 Synergy and Western Power	116kW/464kWh Tesla Battery	DNSP owned, Retailer operated. Virtual sharing Deferment of Network Augmentation
WA, PowerBank 3 Ellenbrook, Perth, FEB 2020 Kalgoorlie; Ashby; Canning Vale; Two Rocks; Vasse Busselton, JUN 2020; Port Kennedy, Perth; Yokine; Parmelia. Synergy and Western Power	116kW (464kWh) Tesla battery	DNSP owned, Retailer operated. Virtual sharing Deferment of Network Augmentation

30 Melbourne council plans city-wide community battery network – pv magazine Australia (pv-magazine-australia.com)

31 Victoria's first 'solar sponge' community battery network to be developed – pv magazine Australia (pv-magazine-australia.com)

5.1.4 Case Study Western Australia Community PowerBank Trials

Figure 13 Powerbank installation in Western Australia

Fulfilling an action under the Distributed Energy Resource (DER) Roadmap, Western Power installed differently designed batteries in PowerBank trials 1, 2, and 3.

Run by WA Government owned retailer Synergy and network operator Western Power, the PowerBank trials involve Local Batteries installed in both metropolitan and regional areas of WA.

The PowerBank schemes allow households with Solar PV to store excess power from their solar PV systems in the Local Battery and providing an alternative storage option to behind the meter storage.

PowerBank 1 was the first time in Australia that a Local Battery had been integrated into an existing Distribution network.

Power Bank 2 was a 24-month trial, with householders able to choose either 6kWhs or 8kWhs of virtual storage, at a cost of $1.60 or $1.90 per day respectively, for the excess power generated during the day from their solar PV systems.

Similarly, PowerBank 3 is an 18-month trial, allows householders to store their excess rooftop solar energy for a subscription of $1.20 per day for 6kWh or $1.40 per day for 8kWh. PowerBank 3 allows customers to accrue excess energy over the course of their monthly billing cycle, providing greater opportunity to offset peak energy consumption. Customers buy back their own stored energy at a lower cost than the retail tariff.

PowerBank 3 trial can offer up to 600 homes virtual solar storage via nine new Tesla PowerBank installations.

Synergy WA Govt owned retailer is managing the PowerBank trial and interface with the community. There are no lock-in contracts for homes taking part in the trial, which will give greater flexibility and choice to customers in deciding how they meet their individual electricity needs. For Terms and

Conditions provided to residential customers seeking to participate see PowerBank Saver Plan Terms and Conditions (synergy.net.au)

Customers receive information on how they can improve their energy use and how to better manage electricity consumption and costs. They also receive seasonal updates on the savings they are making under the trial. Customers in the first Meadow Springs trial collectively saved around $11,000 or an average of $228 per customer off their annual power bills.

The scale and operational benefits of larger batteries also provides a cost-effective storage solution to customers when compared to home batteries.

WA operates separately from the National Electricity Market and WA has slightly different market rules. Legislative changes were introduced to facilitate the PowerBank trials.

The PowerBanks are operated by Western Power to deliver network service and stability benefits on the state's South West grid (SWIS).

Western Power funded the Local Batteries to prove the benefits of the business model. The $100k cost for each battery was funded from Western Power's OPEX budget and revenue from customer subscriptions.

Management of the amount of Solar PV hosting capacity also referred to a network augmentation deferral has value but is not valued by Western Power in the trials.

5.1.5 Case Study NSW Ausgrid

In February 2021, NSW Distribution Network Service Operator Ausgrid commenced a two-year Local battery trial. Commencing in the Sydney suburbs of Beacon Hill and Bankstown, the trial enlists Ausgrid network customers with Solar PV systems[32]. Ausgrid is currently engaging with Lake Macquarie City Council to locate a local battery in its Local Government Area.

Eligible customers can participate by virtually storing up to 10kWh of excess solar energy exports each day which is credited against their electricity use for that day. The participants' credits are calculated at the end of each day and paid out quarterly via bank transfer. There are no costs to participate and customers don't need to change their electricity retailer.

[32] Community battery trial - Ausgrid

Figure 14 Ausgrid battery in New South Wales

Ausgrid's plan is to prioritise areas of the grid where rooftop solar PV uptake is high.

The cost of each battery is around $400,000 and it is estimated they would deliver annual savings of between $100 and $300 a year to consumers.

5.1.6 Case-Study The Beehive Project, Enova Energy

Enova Energy is a community owned energy retailer and registered charity.

The Beehive Project is a multi-partner effort led by Enova Community Energy to trial a shared community battery and peer-to-peer solar energy trading project.

The Kurri Kurri Big Battery project in the Hunter Region was a location chosen by Ausgrid to alleviate zone substation capacity issues. The battery will be operated by Enova to maximise its value at the wholesale level and deliver benefits to energy customers and the community.

It is the first Medium Voltage (MV) battery and will help Ausgrid understand the value of a Local Battery on a MV location.

This project is supported by funding from the NSW Government. Enova acknowledges the funding support from the NSW Government under the Regional Community Energy Fund.

Key Partners in The Beehive Project are:

- Enosi developers of Powertracer, an online peer-to-peer energy web-based trading and sharing platform;
- A research team at University of Newcastle to track and monitor this pioneering project.

Enova will invite at least 500 households with and without roof top solar to participate and living anywhere in New South Wales. The project will enable them to share and trade rooftop solar energy with each other and with the battery itself.

Enova are in negotiation with Essential Energy around other trials in regional NSW.

5.1.7 Case study University of Queensland Battery Energy System

Table 1.1: Battery key figures

Make & model	Tesla Powerpack 2.5
Rated power	1.1 MW
Storage capacity	2.15 MWh (~2 hours at full power)
Depth of discharge	100% of nameplate
Number of battery packs	10 x 215 kWh
Number of inverters	2 x 580 kVA (at 415 Volts)
Physical footprint	44 m² (including clearances)
Total weight	25.7 tonnes (excluding foundation)
Total project cost	$2.05 million ($954/kWh)
Date commissioned	19 November 2019

Figure 15 Key figures for University of Queensland battery project

In 2019, the University of Queensland (UQ) installed the state's largest behind-the-meter (BTM) battery and accompanied UQ's move to be the first university in Australia to participate directly in the wholesale electricity spot market (Wilson, Esterhuysen, & Hains, 2020).

The battery costed in all $2.05 million and was funded through the sale of renewable energy certificates created by UQ's existing 6.3MW behind-the-meter solar PV portfolio. Based on the Q1 performance data, the UQ battery is on track to pay for itself within the eight years.

The UQ-developed Demand Response Engine (DRE) is a cloud-based, data-driven, supervisory control system hosted within Amazon Web Services. It is described as a novel platform in which autonomous, event driven predictive controllers can be designed, simulated, and deployed across UQ infrastructure to help improve and optimise energy asset operation. The battery's Demand Response Engine (DRE) was developed to manage not only the battery but additional demand response initiatives, such as HVAC control, and as the market is developed.

Through a partnership with Enel X, the battery is paid to remain on standby to respond to sudden disturbances to grid frequency from events such as power plants tripping offline. Revenue is earned by bidding this response capability into the NEM's three contingency Frequency Control Ancillary Services (FCAS) markets.

The results show the battery system generated $73,938 in value during Q1 2020:

- 12% or $8,523 was earned through arbitrage alone. The data was heavily skewed towards January, when net revenue was almost double the value earned in February and March combined, due to the underlying pricing volatility in the NEM during January compared to the other months.
- 62% or $46,000 through participation in the frequency control ancillary services (FCAS) market. As a behind-the-meter asset of less than 5MW, the UQ battery currently participates in three (of eight) contingency FCAS markets.

- 26% or $19,415 from the battery's virtual cap contract. Whilst not an exact replacement for a traditional financial cap, this service has substantial value to UQ nonetheless. Refer to section 3.4 for further information.

The soon to be completed 64MW Warwick Solar Farm at a cost of $125 million will support the University's transformation into a "gensumer".

5.1.8 Case Study - Melbourne Solar Sponge Project

Victoria's first 'solar sponge' community battery network to be developed – pv magazine Australia (pv-magazine-australia.com)

In 2010, Yarra City Council established the Yarra Energy Foundation (YEF)[33] as an independent not-for-profit to provide advice to homes and businesses on energy and sustainability.

YEF work across Australia providing professional advice and services such as purchasing Solar PV and Batteries, Power Purchase Agreements (PPAs), and Environmental Upgrade Agreements.

Announced in Jan 2021, the Melbourne Solar Sponge Project is a series of local batteries to be installed across the inner-city suburbs in a joint venture between YEF and the local Distribution Network Service Provider Citipower.

A series of local batteries will be installed across the inner-city suburbs of Melbourne, in a joint venture between local network distribution company CitiPower and the not-for-profit Yarra Energy Foundation. The first battery is expected to be trialed later in 2021.

The project, which is currently in its first phase of modelling and planning[34], aims to develop and roll out a "new" model of community battery ownership that will provide customer, community and network benefits, including acting as a "solar sponge" in areas of high rooftop PV uptake. By taking a share in the batteries, customers can make the most of their investment in solar.

The YEF's project plan is to deliver a community battery as a third party and in partnership with DNSP Citipower. This approach does not include the Council or a retailer.

YEF are proposing a model where residents are able to invest in their local battery and become part-owners of community batteries. YEF report that they have commenced community engagement and financial modelling resulting in interest from investors.

YEF received a grant which was used to set up a business model for scalable delivery. YEF have a hybrid structure which has parent and child entities or subsidiary companies, each subsidiary company, being the owner of a battery. The parent company sets up the infrastructure and runs it and then just charges its costs to each individual battery. The individual battery doesn't have the burden of the set-up costs.

YEF in developing their business case identified that a business case for one battery is much weaker than a business case for a number of batteries within the same business, because the setup costs can be dispersed across multiple batteries. The first battery is anticipated to be loss-making and requires a grant to cover setup costs.

[33] About us - Yarra Energy Foundation (yef.org.au)

[34] Community battery "solar sponges" to be trialled across Melbourne network | One Step Off The Grid

The second and subsequent batteries then don't have to pay for the set up infrastructure but only the BESS system costs and can then expect a return from running that battery. Each of the batteries has a different group of community members who might want to own it.

This model is designed so community energy groups could easily get into owning a BESS without having to go through the painstaking efforts of getting the infrastructure in place.

Key Assets

YEF are currently in negotiation with Battery Equipment suppliers and Electrical Design.

YEF have negotiated a Local Use of System (LUOS) tariff with CitiPower that will be introduced as a waiver of tariff at the time of the field trial starting early 2022.

The LUOS tariff is a lower tariff during peak time when the battery is discharged for customers. The LUOS tariff also includes a margin that works as a subscription for YEF and for each battery.

YEF are currently considering registering the battery as a small-scale generation aggregator (SGA) in-lieu of a relationship with a retailer.

Again the overhead costs of running as an SGA – such as reconciliation and settlements, could be defrayed over multiple assets and with YEF acting as the aggregator.

The benefit of SGA is full access to arbitrage and YEF can trade directly on the market buying and selling as opposed to having to share the revenue with a retailer, further improving the financial performance of the business case.

Pre-requisite Technology

YEF are in partnership with Australian National University (ANU) to develop and design a control system suitable for delivering community energy services.

YEF and ANU propose to use open source software that is in the public domain and able to be further developed and be available to others to accelerate the uptake of community.

YEF and ANU are currently undertaking an analytics projects and pattern analysis of consumption data of the sub network of our field trial to inform the Optimiser.

The aim is to identify seasonal variation in demand and therefore fine tune the forecasting that the optimiser will use to make the right decisions.

Key Resources

YEF are taking an extremely cautious approach with Community engagement citing that it is absolute fundamental, and if this is not done right, then don't even bother (Wallin, 2021).

An essential strategy has been running webinars, educating and helping people get their minds around "What is the community battery? Why does it matter to me? Why should they think about it?". The proposal is that the education piece will lead to an approach to the community about the selected field trial, and allow YEF to talk to them and involve them. YEF understand that an announcement about a field trial in a particular area is contingent on community awareness and support.

This is in stark contrast to an energy sector which expects to make decisions largely in the absence of stakeholders. YEF would like to reverse that by bringing the community on board from day one.

Key Partnerships

The following quotes capture YEF's insights about commercial partnerships:

- You're either completely independent or you rely on others to do it, but financially that's challenging
- The commercial model is really tricky because, as a third party, you're not a retailer, and you're not the NSP that, so you basically have to perform the functions that they would otherwise perform within their respective businesses. (ie a retailer provides billing services, wholesale energy purchasing and price risk management. An NSP provides response services to power outages and some metering services)
- And you have to do it in a very frugal way. Our starting point was to say, we're just going to outsource and we're going to have an upstream retailer. They're the ones that give us access to the electricity market. And we're going to have downstream retailers, the ones that are selling electricity to customers, and we're going to set up relationships with them.

YEF has worked closely with its network provider, CitiPower in order to progress the battery project.

Revenue Streams / ROI

- Financial modelling has commenced and the projections are that it will be difficult to succeed on a purely commercial basis.
- Network support to the DNSP, arbitrage and FCAS are considered likely sources of income – needed to generate profit and return to shareholders/community.

Pursuit Strategy

- YEF are planning to deploy 200 of these systems over the next seven years.
- The plan would be to position themselves as a project management for all community batteries and possibly other markets so that the market facing costs can be shared across numerous projects.

Project Contacts are:
Chris Wallin, Community Battery Project Manager. chris.wallin@yef.org.au
Greg Hannan from Citipower/United Energy

5.2 ARENA Projects

Arena has funded a suite of battery related projects over the past few years.

Presentation: Large Scale Battery Storage: Services and value streams (PDF 448KB) (2109) summarises the results from the Utility Scale battery trials at Hornsdale (100MW), Ballarat (30MW), ESCRI (30MW), Gannawarra (25MW), and Lake Bonney (25MW).

Testing the Performance of Lithium Ion Batteries is an ongoing trial by ITP renewables and live performance of different battery technologies can be viewed at the ITP Battery test centre

Consumer Energy Systems Providing Cost-Effective Grid Support on Bruny Island reported mixed results from consumers.

Community Models for Deploying and Operating DER project by ANU provided the main insights providing both techno-economic analysis and social investigations to investigate implementing community scale batteries.

5.2.1 Synergy Alkimos beach Energy Trial

The Alkimos Beach Energy Storage Trial (ABEST) received $3.3 million in funding from the Australian Renewable Energy Agency (ARENA) through its Emerging Renewables Program.

The project was based around a community-scale battery storage, high penetration rooftop solar PV and energy management within the new residential suburb of Alkimos Beach in WA.

The project involved Synergy as a major Western Australian based generator, DevelopmentWA the Western Australian Government's development agency and Lendlease property developer as partners in the Alkimos Beach housing development.

Undertaken from 2016 to 2021, the aims of the five-year trial (Synergy, 2021) were:

- Understanding electricity supply reliability when provided by a combination of renewable energy generation and integration (enabling) products.
- Feasibility of a new energy servicing model that virtually connects individual household solar photovoltaic (PV) systems with a community-scale energy storage system.

Through the participation of over 100 households, a combination of initiatives were tested, these were:

1. An Energy Smart Home Package. Participant rebates valued at $4,150 for an energy efficient hot water system; a minimum 1.5 kW solar PV system (mandatory building requirements) and further rebates for additional energy efficiency devices.
2. Community Scale energy storage. A 1.1 MWh lithium-ion energy storage system was used to manage peak demand within the suburb. That is charging from the network during periods when demand is low (early afternoon and overnight) and discharging during peak demand periods (late afternoon and early evening).
3. New electricity retail products and services. Peak Demand Saver Plan (PDS) tariff with the virtual battery offering to householders for $11/ month which allows them unlimited storage. Synergy Smart Response (SSR) program and using Direct Load Control technology on household air conditioners and controlling their contribution to peak demand on the electricity network.
4. New metering and data platforms.
5. An educational 'eco-coaching' behavioural change program to help participating residents effectively manage their energy usage and assist to reduce their overall electricity consumption

Over the entire life of the ABEST project, approx. 3 per cent of the 119 participants benefited from the PDS tariff compared to the alternative regulated Home Plan (A1) tariff. This translated to participants saving a total of $81,376 during the trial.

5.2.2 Reposit Power Trial

In 2014, ARENA supported Reposit's Intelligent Storage for Australia's Grid project and at a time when battery storage model was not well understood (Reposit, 2016).

The Reposit Power project pioneered the development of distributed control systems to monitor, optimise and control grid-connected energy storage. Reasoning that, like solar, households would lead in the adoption of batteries.

The Reposit box (meter and battery storage control module) gathered large amounts of electricity usage and generation data and help train predictive algorithms.

A key part of Reposit's control system is the simultaneous delivery of multiple energy services from a single electricity storage system and to co-optimise these systems.

The energy services were:

- Tariff arbitrage. Lowering electricity bills by charging from solar and discharging back into the home.
- Wholesale electricity market trading, Ancillary market trading, Demand management for the benefit of the local distribution network and earnt by the customer as GridCredits.

The Canberra based pilot demonstrated the value of smart storage and how residential solar and energy storage systems can operate in Australia's electricity grid.

As part of the trial, Reposit successfully deployed five full home energy systems, comprising solar, storage and Reposit's technology.

These customers were able to make significant savings on electricity bills, with one customer saving up to $3,000 per annum. These savings were through a combination of solar (for those that did not have it before the trial commenced), solar-charging of the battery, smart-charging of the battery at off-peak times, through market operations and through behavioural change.

5.2.3 Australian National University Community Battery Models

As part of the ARENA Community Models for Deploying and Operating DER project, ANU delivered a number of reports (ANU, 2020a, 2020b, 2021) to support the following:

<u>Summary of findings</u>

Community-scale batteries have the potential to play an integral role in Australia's transition to a decentralised grid. These batteries are connected to the distribution network and have power capacities of up to 5MW. Our work has shown that the location and sizing of this type of storage makes it uniquely suited to providing social, economic and technical benefits to the broader energy system.

There is widespread interest in shared storage and in community energy more generally, from industry, governments, new entrants, and the community at large. In Western Australia, several trial community-scale batteries projects are underway. The success of these projects has led to a push to understand how best to operate community-scale batteries on the rest of Australia's electricity network, the national electricity market (NEM).

The wide-scale roll-out of community-scale batteries on the NEM faces challenges; our research revealed that projects owned by Distribution Network Service Providers (DNSPs) face regulatory barriers, retailer- owned models face trust issues, and community-owned models face logistical issues. The challenges and also the benefits are outlined in the first two sections of this report.

Key Lessons Learnt

1. Community-scale batteries are already financially viable, particularly if FCAS markets can be accessed
2. Reduced local network tariffs are crucial for incentivising battery charging from locally generated solar energy and sale of energy to local customers
3. Householders care about more than just affordability when it comes to energy storage
4. Network tariffs and market signals shape how the battery's actions contribute to hosting capacity
5. Community-scale batteries can increase the amount of DER that can be integrated into the distribution grid
6. The technical capability for implementing community-scale storage on the NEM already exists
7. Only DNSP-owned community-scale batteries currently require regulatory exemptions. All other models investigated can proceed within the current rules and regulations
8. Industry professionals saw significant potential benefits of community-scale batteries, including over behind the-meter (BTM), virtual power plant (VPP) storage.

5.2.4 SA Power Network's Flexible Exports for Solar PV Trial

The SAPN trial acknowledges electricity distribution network has a limited capacity to accommodate export from Solar PV systems and reverse power flows at time of peak generation in the middle of the day. DNSPs have had to impose static or zero export limits for recently connected solar PV systems in constrained parts of the network. Creating an inequitable system where early adopters of rooftop solar "use up" the available grid capacity, and late adopters are constrained.

The aim of the trial was to test a flexible connection option for consumers with Solar PV systems as an alternative to permanent zero-export settings in congested network areas (SAPN, 2021a, 2021b).

The "Flexible Exports for Solar PV" trial was a collaboration between SA Power Networks, AusNet Services, Fronius, SMA, Solar Edge and SwitchDin.

The trial co-developed an end-to-end technical solution, using smart inverter technology enabling customers' inverters to automatically adjust their export limits every five minutes based on a locational, dynamic limit signal provided by the DNSP.

The Project tested the customer understanding and acceptance flexible customer connection offer over a 12-month period and field trial.

The key learnings (SAPN, 2021b) were

1. Customer messaging must be broad and deep to cater for audiences at different levels of engagement.
2. To enable flexible exports under the current regulatory framework, the model standing offer (MSO) needed to be modified

3. Agile delivery methods are helpful when undertaking a project in this space as it's new and the risks/challenges/opportunities are unknown
4. Various aspects of the CSIP implementation guide (and therefore CSIP-AUS) are open to interpretation. Need to provide clarity around these aspects in the final CSIP-AUS.

5.3 Transmission Grid Connected Utility Storage

Over the next 20 years, Australian Energy Market Operator (AEMO) has conservatively estimated that up to 180 Utility scaled, Transmission network connected batteries will be deployed into the National Electricity Market.

At the transmission grid level, the Utility-scale energy storage can:

- shift the timing of renewable energy production,
- reduce the magnitude of new intra-regional transmission required
- provide firming support during peak loads or when renewable production is low
- Provide FCAS

Refer to Appendix A for a list of the Transmission Network Connected Battery projects and informed by the Big Battery Map[35].

5.3.1 Case Study - Hornsdale Big Battery

Constructed in 2016, the Hornsdale Power Reserve (HPR) is 100MW/129MWh with 50MW/ 64.5MWh expansion and costing $90 million. The Hornsdale Power Reserve is co-located with the 316 MW Hornsdale wind farm.

Using Tesla Powerpacks with fast ramping capability, HPR is exceeding expectations, able to sense a frequency deviation within milliseconds and able to switch from charging at a rate of 919 kW to discharging at a sustained rate of 1,099 kW well inside the traditional 2second timeframe.

HPR has 70MW of capacity (and a small amount of storage) contracted to the South Australia government for the provision of network services.

Another 30MW, and about 90MWh of storage, is sold into the wholesale market by time-shifting the output of wind, or by arbitraging spikes in prices. It also plays in the frequency and ancillary services market (FCAS). This response was sustained for 304 seconds, after which frequency restored to within the normal operating range."

HPR played a critical role during the 18-day "separation" when a tornado tore down the main link to Victoria.

In 2019, HPR reduced costs in the National Electricity Market by $116M[36] through the provision of Contingency and Regulation Frequency Control Ancillary Services (FCAS).

[35] Big Battery Storage Map of Australia | RenewEconomy

[36] Revealed: True cost of Tesla big battery, and its government contract | RenewEconomy

5.3.2 Case Study ESCRI, Dalrymple North

Constructed in 20xx and owned by ElectraNet, the Energy Storage for Commercial Renewable Integration (**ESCRI**) in Dalrymple North, SA. The ESCRI is a 30MW, 8MWh battery and cost approx $30 million[37]

The ESCRI is generating significant income from energy and FCAS markets for the third-party operator, AGL. The ESCRI has been so profitable it repaid the ARENA grant of $12 Million.

5.4 Other DER trials - Virtual Power Plants, Microgrids, Peer to Peer

There are many initiatives to grapple with new ways of accommodating roof top solar, producing and using electricity and they overlap with the value offered by local batteries. The market for solutions is shaped by market rules.

Two examples that the electricity system is responding to challenges at the local level are the wholesale demand response mechanism and proposals for a two sided market. The wholesale demand response mechanism was implemented in 2021 and allows aggregated, controllable demand to bid into the wholesale market at the same price as generation. The two-sided market has been offered as a vision by the Energy Security Board (ESB) and provides shape to the Post 2025 Electricity Market Design Project.

In advance of new market rules, trials and feasibility studies have been underway to explore the value offered by Virtual Power Plants (VPPs), Microgrids and Peer to Peer trading. This section highlights two examples, but full treatment is beyond the scope of this report.

Virtual Power Plants (VPPs) refer to initiatives where multiple solar systems, batteries and/or loads such as pool pumps are controlled to respond to price signals on the wholesale electricity market. Many of the trials have occurred in South Australia, in part because household batteries have been subsidized and promoted in SA. Ten VPP schemes[38] are listed on the battery subsidy page and promoted as ways to make more income from a household battery. AEMO provides a summary of VPP trials on its website[39].

Since VPPs develop the systems to control equipment, these schemes could be deployed to reduce peak demand and peak export and therefore overcome constraints on the local electricity network. Creating a market opportunity out of network constraints is a different design approach to that taken by Energex via dynamic operating envelopes. It should be noted that without information about local network constraints, the operation of VPPs can cause network overloading problems.

Microgrids in general refer to systems which can operate independently from the main grid. This definition covers a host of applications including emergency supply when the grid has failed. Microgrids have traditionally been delivered via a standby diesel generator. Renewable microgrids are likely to replace the diesel generator with a local battery because the each microgrid needs to control enough generation and load to match supply and demand. The single largest asset in the microgrid therefore becomes essential to microgrid control. The Federal Government has run two rounds of the Remote and Regional Communities Reliability Fund Microgrids Program[40] for microgrid

[37] Dalrymple ESCRI-SA Battery Project – ElectraNet

[38] https://www.homebatteryscheme.sa.gov.au/join-a-vpp

[39] https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations

[40] https://business.gov.au/grants-and-programs/regional-and-remote-communities-reliability-fund-microgrids

feasibility studies. ARENA[41] is currently designing its scheme for funding the implementation of microgrids post-feasibility.

Peer to Peer trading proposes that if sellers can find buyers, there should be no need to operate through the wholesale electricity market. This idea might be the forerunner to local energy markets and two-sided markets but many elements of accounting in the existing electricity system need to be adjusted to accommodate these ideas. Early peer to peer schemes operate with electricity retailers in order to overcome these accounting issues. Three platforms provide examples, Power ledger (see Synergy trial), Oxamii (https://www.oxamii.com/)and Enosi (https://enosi.energy/). The latter two operate through Energy Locals. Blockchain has been proposed as one of the technologies that makes peer to peer trading efficient and Powerledger has been an Australian pioneer for blockchain use in the energy system.

Refer to Appendix C for a full summary of DER and VPP trials.

5.4.1 Synergy, Western Australia

Synergy - Peer-to-peer Electricity Trading

5.4.2 Heyfield

Heyfield is a data led microgrid project. Although no modelling of the details has commenced, it is likely that local batteries will play a strong role. The community has already rolled out significant energy and water savings and won an award for its sustainability flag program.

A three-pronged approach allows the community to deliver DER actions that make sense regardless via a first step focused on energy efficiency, solar PV, demand management, batteries. One aim will be to ensure the appliances and systems are all made 'smarter' at the time of investment in readiness for the control that will be needed in the two future options: A virtual power plant or a microgrid. The modelling will seek to answer the following:

1. VPP - What is constraining Heyfield from installing more solar or from making better use of solar - can energy trading and additional management unlock more value?
2. Microgrid - what extra costs and benefits are involved in being able to disconnect from the grid at times and operate completely self-sufficiently?

$1.7m Heyfield project which is funded through the Regional and Remote Communities program and has also been instrumental in identifying and seeking funding for other community energy projects in Victoria and SA.

[41] https://arena.gov.au/funding/regional-australia-microgrid-pilots-ramp/

6 Noosa Electricity Grid

Six Zone substations and one bulk supply station (Sunrise Hills) supply the Noosa LGA.

The capacity of each substation is listed in the table below:

Table 3 Zone Substations in the Noosa Region

Code	Zone Substation (Voltages)	Peak capacity
NVL	Noosaville (132/11kV)	141MVA, slightly lower in summer
TWT	Tewantin (33/11kV)	58.7MVA
CRY	Cooroy (33/11kV)	30MVA
BMT	Black Mountain (33/11kV)	17.9MVA
COR	Cooran (132/11kV)	36MVA, 35.2 in summer
PGN	Peregian (33/11kV)	39.6MVA. *Only one marked as constrained*
SRH	Sunrise Hills Bulk Supply (132/33kV)	143 MVA

As part of this report, an additional series of graphs and analysis was generated from the 30minute dataset for each zone substation which dates back a decade.

Further work could develop this dataset to map the solar contributions, the value of hot water loads if shifted to daytime and the potential electric vehicle load.

The Distribution Annual Planning Report(DAPR) (Energex, 2020) is a primary source of data for the Energex network at the 132kV and 33kV voltage levels. At the main distribution voltage (11kV and 415V) data is much more limited.

The location of each zone substation is shown on the map below:

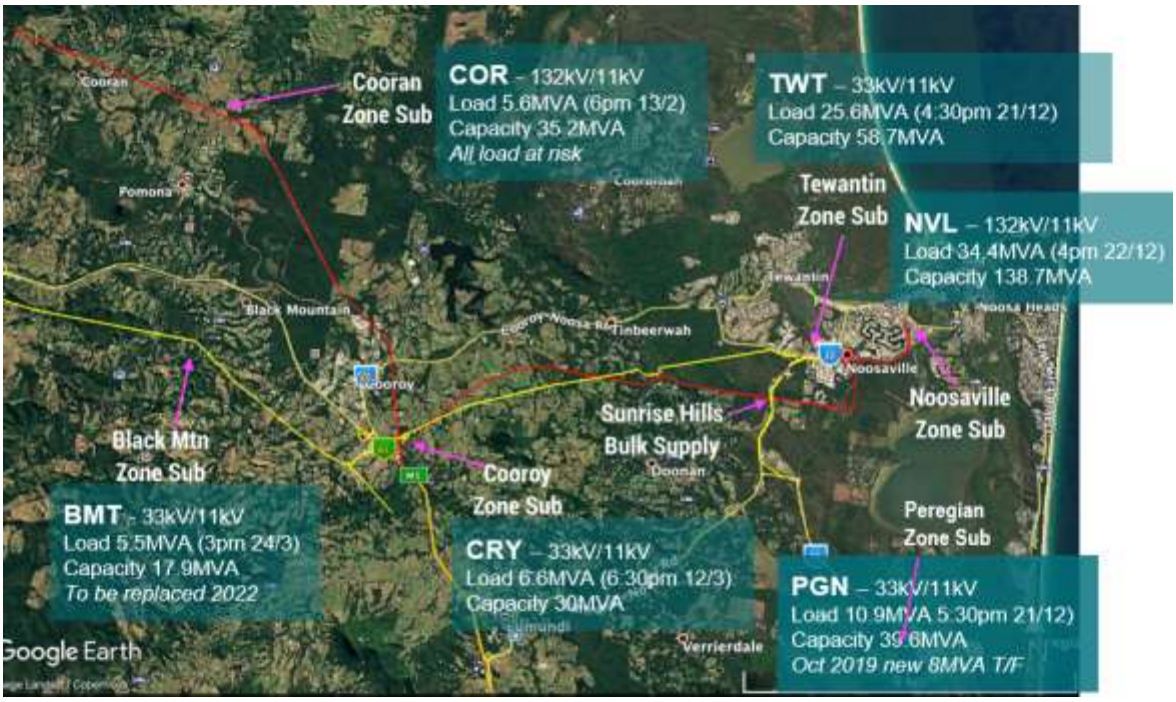


Figure 16 Zone Substation locations

Performance data is published for each Zone substation.

- SAIFI refers to the average frequency of outages
- SAIDI refers to the average duration of outage

The graphs below for the six substations highlight much poorer performance in 2017 for a number of substations. Network businesses use these statistics, along with forecasts of assets reaching full capacity to identify investment priorities across their service region.

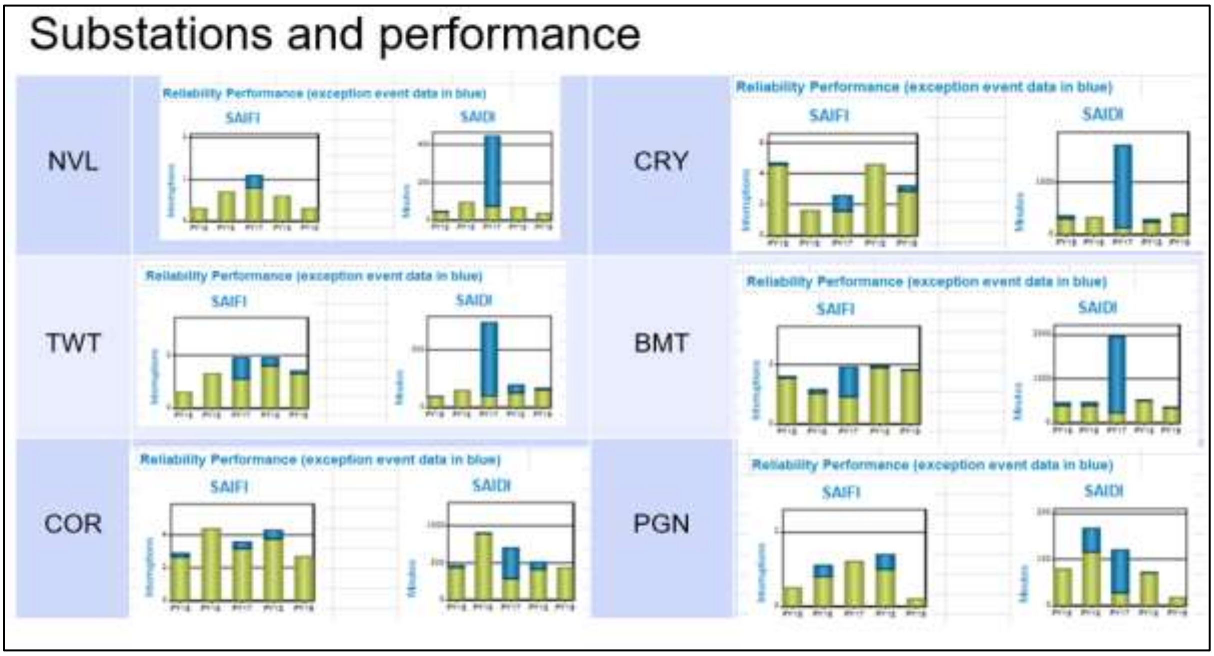


Figure 17 SAIDI and SAIFI indicators for each Zone Substation

The meetings held with Energy Queensland and engineers with knowledge of the local Energex grid continue to identify the opportunity to look more closely at the data for the low voltage network. This data is not publicly available and it is unclear how well Energex monitor the local Noosa energy system, and if they indeed have a suitable level of visibility on local voltages and constraints.

7 Recommendations

This assessment of local batteries demonstrates the importance of designing local batteries for community beneficiaries. If batteries are deployed with commercial aims, important local needs may not be met.

(ANU, 2020a) identified five essential benefits of Local batteries to evaluate future community lead trials and business models.

1. **Fairness and equity.** To improve fairness and equity, models must consider different stakeholders, particularly “solar haves” vs “solar have-nots” and other differing levels of resources between energy users that affect capacity to participate (financial and non-financial). Models need to consider: who gets to participate? Customers close to the battery, within a suburb or within the whole DNSP? Also important is the choice of who gets access to the battery in an outage. Are service groups critically reliant on energy supply prioritised (e.g. the elderly in a heat wave)?
2. **Trust and transparency.** To build trust in the energy system, models must be open and transparent with respect to how financial and non-financial costs and benefits are distributed amongst stakeholders and how decisions are made.
3. **Hosting capacity.** Batteries can improve the hosting capacity of the network i.e. the amount of solar generation and electric vehicles that can be connected to the network, to different degrees, based on how their behaviour relates to local network conditions.
4. **Local resilience**. Local batteries can contribute to bolstering the resilience of the local community, including through local jobs and training, keeping money circulating within the community, and increasing the physical resilience of the local power supply to disturbances.
5. **Cost-effectiveness**. The cost-effectiveness of a local battery should be compared to other options, such as network upgrades, distributed batteries and tariff changes.

The following diagram shows that the battery design philosophy alters the performance of the battery. Community stakeholders are best placed to nominate the flow of benefits that are needed.

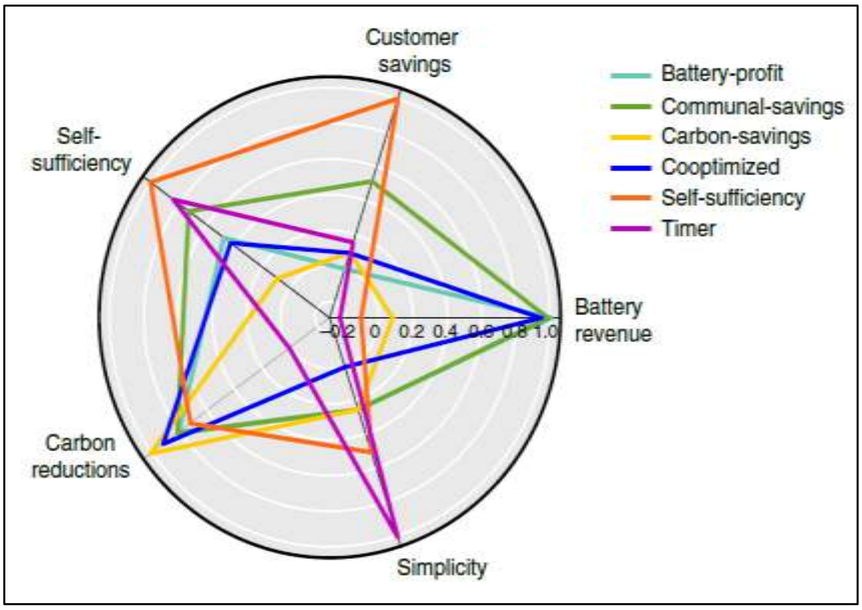


Figure 18 Battery performance when algorithms are optimised for different priorities (Ransan-Cooper et al, 2021)

Timer control (purple) excelled on simplicity and self-sufficiency but performed worse on carbon reductions, battery revenue and customer savings. The three algorithms that performed well on battery revenue produced lower customer savings than the algorithm optimised for self-sufficiency (orange). The yellow line indicating optimisation for carbon reductions has poorer outcomes against most other measures but, except for timer control, most of the other algorithms delivered high carbon reductions.

These results emphasise trade-offs that are best discussed and resolved in the local context with the community.

Recommendations

With a design for community challenge in mind, the following strategies are recommended to maintain momentum for Noosa Shire and ensure it keeps pace with the opportunities presented by a changing electricity market:

1. Continue to build constructive relationships with stakeholders such as Energex, Energy Queensland and the community.
2. Continue to pursue information and data collection, particularly to identify costs placed on Noosa customers by constraints, being mindful of the value of such data in the market place, and value to emerging commercial players such as an aggregator or Virtual Power Plant operator.
3. Develop a Lobbying strategy
    - Engage with Energy Qld and Energex as the local Distribution Network System Provider to understand local constraint issues, policy directions and operational opportunities for local batteries.
    - Promote the advantages of Noosa including ZEN Inc's work, community values and community engagement.
    - Highlight the benefits of the Western Australian Powerbank trial and other state initiatives to the Queensland Government (noting that Powerbank is aimed at the residential sector)
4. Open discussions with potential delivery partners and organisations with similar values and objectives such as Enova Energy, Power Club and Yarra Energy Foundation.
5. Consider the suitability of different business models including Microgrid, Aggregator, Virtual Power Plant as well as low voltage, medium voltage and business BESS applications.
6. Consider the benefits and risks associated with ZEN Inc. or Noosa Shire council becoming the local aggregator and VPP operator.
7. Investigate other delivery models used by Councils. For example, the energy service company model operating successfully in the UK and 51% owned by the local authority.
8. Develop a local register of Distributed Energy Resources (DER) with the view of supporting a future aggregator enterprise. DERs are controllable loads, solar PV systems, batteries and electric vehicles. This is independent of ZEN Inc. choosing to become an Aggregator but would be valuable market intelligence for an Aggregator[42].
9. Maintain a watching brief on the AEMO development of a DER register intended for the whole national electricity market[43].
10. Develop greater understanding of:
    - how a Local Battery is integrated into the Network

[42] In future there will be value in offering 1 sec monitoring and transparency to Energex from local solar and battery installations including electric vehicles, for example

[43] AEMO | Distributed Energy Resource Register

- Electricity Supply Industry stakeholders and Energy Market Reforms
- Limitations and the ability to address network issues.
- The extent to which zero emissions will be supported by renewable energy within the Noosa Shire LGA and the possible need for future renewable imports. This informs the ambition for producing flexibility locally with battery storage.

11. Deliver a co-design workshop with key stakeholders such as Council and Energy Queensland to explore the project delivery options, engagement process, the role of Local Government, system design considerations and any other relevant issues.
12. Continue to scout for best locations for Local Battery systems. Locations with loads, space for solar and batteries and access to electrical infrastructure provide access to more value streams. Remote feeders and outlying communities are more likely to have constraints and to provide a higher value for improved reliability.
13. Investigate the suitability of areas with large roof spaces e.g. Shopping Centres such as Noosa Junction, Noosa Civic and industrial estates e.g. Noosaville and Cooroy Industrial Estates. Also a combination of businesses with large roof space and industrial sites e.g. Pomona in conjunction with local businesses from each area acting as an Industry Reference Group to ZEN Inc.. .
14. Further develop criteria around the location of a Local Battery such as the colocation with large electrical loads or locations with additional capacity for solar, transport or parking infrastructure including Swap and Go batteries

8 Appendix A - Resources

Resources

- [Webinar recording: What's the role of community batteries in the response to the climate emergency?]

9 Appendix B - Transmission Connected Battery Systems

Table 4 Transmission connected battery systems

Location and Owner	Size and Technology	Operational:	Value Capture
SA, Hornsdale Neoen	150MW/194MWh	Est 2017 Expanded in 2020	System security; FCAS; Arbitrage; Trialling synthetic inertia.
SA, Dalrymple North ElectraNet Operated by AGL	30MW/8MWh Samsung	2018	FCAS; Islanding services in local area; Located adjacent to wind farm.
SA, Lake Bonney Infigen	25MW/52MWh Tesla	2019	FCAS; Energy arbitrage; Located next to wind farm.
SA, Lincoln Gap Nexif	10MW/10MWh Fluence	Operational 2021	Located next to Lincoln Gap wind farm. Likely to be expanded
SA, Playford Utility battery GFG	100MW/100MWh	Operational: 2022	Contracted with SA government, to assist Whyalla steel.
SA, Morgan Origin Energy	30MW/NA	Operational 2022:	To be co-located with solar farm
SA, Torrens Island, AGL	250MW/250MWh	Operational: 2023	May be upgraded to four hours storage or 1,000MWh
SA, Lionsgate, CEP Energy	150MW/NA	Announced	To be built at site of former Holden plant.
VIC, Gannawarra Edify	25MW/50MWh Tesla	2019	First battery located next to solar farm, contracted to EnergyAustralia.
VIC, Ballarat Ausnet	30MW/30MWh Fluence	2019	Located at network junction, contracted to Energy Australia.
VIC, Bulgana Neoen	20MW/34MWh Tesla	Operational 2021	Located next to Bulgana wind farm, originally designed to help power Australia's largest greenhouse.
VIC, Victoria's Big Battery, Neoen	300MW/450MWh Tesla Megapack	Operational: 2021	Mostly contracted to AEMO to provide system services that will allow capacity of main transmission link to NSW to be increased. Also big arbitrage play.
VIC, Sunraysia, Maoneng	50MW/100MWh	Operational: 2023	Contract with AGL.
VIC, Jeeralang Energy Australia	350MW/1400MWh	Operational: 2026	To partially replace Yallourn coal generator
VIC, Loy Yang AGL	200MW/800MWh	Announced	To partially replace Loy Yang.

Vic, Deer Park Energy Hub, Melbourne, Lumea (TransGrid)	300MW / 580MWh		First to be fully financed without using government funding or contracts. and importantly will be targeting “spot” arbitrage markets and also the frequency control market and other grid services.
NSW, Wallgrove Transgrid	50MW/75MWh Tesla Megapack	Operational: 2021	Fast frequency response and inertia, to be operated by Infigen Energy.
NSW, New England UPC/AC	50MW/60MWh	Operational: 2022	Supported by NSW government, to be built next to large solar farm
NSW, Riverina Edify Energy	100MW/200MWh	Operational: 2023	To be located next to Darlington solar farm, mostly contracted to Shell as part of NSW government supply contract.
NSW, Eraring Origin	700MW/2800MWh	Operational: 2022	To partially replace Eraring coal generator and built over three stages.
NSW, Kurri Kurri, Hunter Valley CEP Energy	1200MW/NA	Announced	Would be biggest battery facility on main grid if built.
NSW, Liddell AGL	150MW/150MWh	Announced	Could be upgraded to 500MW.
NSW, Sapphire CWP	30MW/30MWh	Operational: 2022	Supported by NSW government, to be located next to existing wind farm and planned solar farm.
ACT, Queanbeyan GPG	10MW/20MWh	Operational: 2021	Contracted with ACT Government.
QLD, Wandoan South Vena Energy	100MW/150MWh Doosan	Operational: 2021	First big battery in Queensland, will be contracted to AGL and be located next to big solar farm.
QLD, Tarong Stanwell Corp	150MW/300MWh	Operational: 2023	To be built next to Tarong coal fired generator.
QLD, Bouldercombe Genex	50MW/75MWh	Announced	Proposed to be built next to sub station.
QLD, Western Downs, Neoen	600MW	Proposed	To be built next to 400MW solar farm
QLD, Great Western, Renewable Energy Partners	20MW/200MWh	Proposed	To be built next to proposed 250MW solar farm and existing Kogan coal generator.
QLD, Wambo Owner: Renewable Energy Partners and Cubico	Size: 50MW/200MWh	Proposed	To be built alongside proposed 500MW wind farm, which has planning approval.
QLD, Coopers Gap AGL	100MW	Proposed	Would be located next to existing wind farm
QLD, Banana Range EDF Renewables	50MW/50MWh	Proposed	To be built next to 280MW wind farm.
QLD, Kaban Neoen	100MW	Proposed	To be built next to 157MW wind farm

10 Appendix C - Full List of DER and VPP trials

Table 5 Distributed Energy Resources (DER) and Virtual Power Plant (VPP) trials

Trial Location Parties	Description	Size / Scale / Scope	Relationship to 2SM	Value Capture
VPP Demonstrations (NEM wide) AEMO, third party aggregators and VPPs	Develop systems and processes for AEMO to receive operational data from VPPs and test VPPs providing contingency frequency control ancillary services.		Wholesale market participation of end users through aggregator.	Capability to provide FCAS.
SA Tesla VPP, SA (2019-2022) SA Government Tesla	First participants in the VPP Demonstrations program	Up to 50,0000 systems, up to 250MW in aggregate	Wholesale market participation of end users through aggregator.	Capability to provide FCAS.
Simply VPP, SA (2020) Simply Energy SAPN Greensync Part funding by ARENA	Integration and orchestration of DER	>1,000 systems	Role and interaction of VPPs, networks and other market participants through the DSO and DMO platforms.	Testing the ability to send signals to VPP aggregators to modify behaviour based on network conditions and price.
Advanced VPP, SA (2020) SAPN Tesla CSIRO	Testing dynamic export limits to maximise solar and battery (or VPP) output to the grid.	Concept and in field testing on a limited number of sites and systems	Platform for DER participation in wholesale market	
Evolve (2019-2022) ACT, NSW, QLD ANU and ZepBen with utilities in Queensland and NSW Aggregators such as SwitchedIn and Reposit	The project aims to increase the network hosting capacity of distributed energy resources (DER) by maximising their participation in energy, ancillary and network service markets, while ensuring the secure	Multiple demonstrations across 3 states	Dispatch DSO capabilities DMO functions and capabilities	

	technical limits of the electricity networks are not breached. The project will development of software systems that can be used by aggregators to manage DER.			
DER Max (2020-2022) National program AEMO, DNSPs, ARENA, various other participants.	Proposal to develop systems as well as test capabilities to provide services, functions and responsibilities required to integrate and optimise DER to maximise consumer value.	Trial program will cover up to 5 state-based trials and large number of customer sites.	Dispatch Network operations (DSO, DMO)	Distribution network markets and services.
Solar Enablement Initiative QLD Energy Queensland, UQ	Develop a network analysis tool to assess the impact to the network of additional Solar PV.	Proof of concept trial across a limited number of sites	Provide DNSPs with better visibility of the operational conditions of networks PowerPoint Presentation (arena.gov.au)	Network operations to enable greater distribution network and DER flexibility
Networks Renewed (2019) Vic and NSW AusNet, Essential Energy, UNSW	The key focus was to demonstrate that both solar and batteries can support network voltage.	Small number of customers across 2 trials in Vic and NSW	Microsoft Word - FINAL Networks Renewed - public dissemination report v8[JE].docx (uts.edu.au)	Demonstrate capability to provide network services
Project Consort, TAS TasNetworks, Reposit Power, ANU, UTas and USydney	Develop an automated control platform and new payment structures that will enable consumers with battery systems to provide support services to a constrained	Testing concept in restricted geography – Bruny Island.	consort-project-results-lessons-learnt.pdf (arena.gov.au)	Bidding Dispatch Settlement Capability of DER to provide network services

	electricity network.			
SA Home Battery Scheme (2022) SA Government		40,000 systems, 200MW in aggregate.	DER incentive	
NSW Empowering Homes, (2022-2029) NSW Government		Up to 300,000 systems, up to 1,500MW in aggregate.	DER incentive	
VIC Solar Homes, VIC (2022-2029) VIC Government		Up to 10,000 systems, up to 50MW in aggregate.	DER incentive	

11 Appendix D – value streams different terms used and clustered benefits

The following studies have been used to check that all possible value streams are explored in this report:

- Schmidt
- Rocky Mountain Institute
- Ausgrid report
- Martin et al – list of benefits from lit review plus an interesting causal diagram (not loops)
- ANU
- AECOM – grid to garage
- IRENA
- Englberger

Value streams can be collated into distinct clusters that are delivered by particular behaviour of the battery. The following discussion synthesises the value streams identified in the above reports into the following clusters:

1. **Energy shifting** (daily storage behaviour) which could also produce value streams from:
   - demand management
   - freeing up capacity
   - deferred and avoided investment in network and centralised generation
   - local voltage support
2. **Responding to sudden changes in the supply / demand balanc**e. Unlocking commercial value would involve access to FCAS markets and the capability to bid appropriately.
3. **Power quality** – there may be local power quality benefits. The possible issues and the control arrangements to unlock benefits would need to be investigated further.
4. **Back up supply** to serve loads in emergencies and improve reliability
5. **Non-market (societal) value**.

1. Energy shifting – value unlocked

The main role of a battery will be to move energy from times of surplus to times when it is needed. It is likely this will occur every day and in some cases we could envisage two cycles a day – eg a daytime charge of solar energy, discharged during busy times in the evening, followed by an overnight charge of surplus wind, discharged at breakfast time before the sun rises.

Prices on the market follow a pattern of low and negative prices when there is surplus renewable energy and high prices during higher load times. Buying low and selling high on the energy market is known as energy arbitrage.

Buy low, sell/use high

All the following terms are used to refer to this phenomena in the reports above:

- Energy arbitrage
- Spot market trading
- Market arbitrage
- Wholesale revenue

- Wholesale market trading
- Energy storage – intraday
- Shift energy /load shifting
- Grid power fluctuation mitigation

Related terms refer to how the benefits flow, but the behaviour remains as storing surplus/cheap for times of need / high cost on an intraday basis:

- Time of use bill management
- Reduced bills, savings on electricity bills
- Increased PV self consumption / local consumption (which reduces system losses, although there is a round trip efficiency loss of energy through the battery)
- Consumer tariff reduction
- Tariff arbitrage
- Energy storage driven electricity price-cost reductions
- Time (energy cost) shifting
- Peak shaving / peak demand lopping
- Valley filling or load levelling
- Future demand response participation (in DER markets)
- Firming for power purchase agreements (better match of demand and supply within the PPA contract)
- Market price mitigation (if exposed to market pricing)
- Longer term price risk mitigation

Shift or avoid energy infrastructure investment

With a commitment to *correct sizing, optimisation and management*, reducing local solar exports and reducing local peak demand can be used to consistently reduce peaks and constraints. The value flows from energy arbitrage are not simply about daily behaviour. The market signals are deliberately intended to drive investment in generation and network infrastructure. Reliable demand management therefore has a premium value when it can defer or replace investment elsewhere in the system.

a. Generation

For existing solar:

- Creating capacity for increased solar investment
- Using solar energy that is currently unused under export constraints
- Renewable generation and dispatch support
- Better integration and smoothing of local, distributed, variable renewable energy

For renewable energy generally:

- Renewable integration – intermittency mitigation, maximising intermittent generator utilisation
- Reduced renewable energy curtailment
- Decarbonise the electricity grid (duplicated under broader societal / off-market values)

Replacing existing generation or avoiding investment in new fossil fuel generation:

- Low cost capacity

- Replace peaking capacity
- Fuel savings for gas peaking plant

b. Network infrastructure

For new loads such as electric vehicles:

- Creating capacity for new loads (kWh)
- Creating capacity for high demand (kW) (such as fast charging)
- Decentralized energy storage support for electric vehicle fleets
- Servicing local demand and usage profiles

For customers exposed to demand charges or limits on capacity:

- Demand charge reduction
- Peak shaving
- Virtual cap contract

For network investments and performance

- Transmission congestion relief
- Transmission upgrade deferral
- Distribution upgrade deferral
- Increase hosting capacity

Better utilisation of existing network infrastructure ultimately lowers the costs for all users of the network. We don't yet know if there is a beneficial calculus for increased activity at the local level that drives *more* network infrastructure investment. In a growth area or in a location with aging infrastructure, new and upgraded network capacity may be an added bonus of local generation, storage and load investments but in many places staying within the bounds of existing network infrastructure will generate the most value.

2. Responding to sudden changes – value unlocked

Local batteries are unlikely to use regulation FCAS as a value stream. Responding to sudden changes can be more lucrative and a battery can attract revenue from contingency FCAS markets. This section explains the FCAS markets and highlights the opportunities to respond to sudden changes in the supply / demand balance.

Explanation of regulation FCAS

Supply /demand imbalances in the electricity market cause voltage and frequency to rise or fall and the role of the energy market operator (AEMO) is to continually manage this balance. It starts with forecasts of the supply needed to meet the load and then dispatches the generation by price to match the forecast load. The lowest cost generators are dispatched almost all the time and the highest cost 'peaking' generators are only dispatched when the highest loads are reached. (This process determines the price of electricity on the wholesale market and explains why it varies at different times of day and year). During normal operation the forecasting and matching processes will often be imperfect so a frequency markets are used to fine tune the load to supply and keep the frequency at 50hZ and the voltages steady. The regulation Frequency Control Ancillary Service

(FCAS) market achieves this normal finetuning. Prices in this market are generally below the price of energy[44]. It is easy for a large centralised generator that is operating in the market to adjust its output up and down slightly and maintain the supply / demand balance. If energy (kWh) are sold into the FCAS market, it is unavailable to the energy market so, for simplicity, many generators only bid into the wholesale energy market.

Contingency FCAS and other methods of managing sudden changes in load and frequency

The largest disruption in the electricity market is caused by a change in a large flow of energy. This can happen when a generator or a transmission line fails and tends to be large changes of 100MW or more. Smaller changes are managed fairly easily within the regulation FCAS mechanism. When markets are smaller, the assets available to respond within that region becomes important and the size of the failure that can affect the frequency shrinks. (eg when a region is disconnected from the NEM for a period of time). Contingency FCAS is provided in 3 timespans – 6 seconds, 60seconds and 5 minutes. The 6 second market appears to be the most lucrative and is dominated by big batteries, which act faster than other generators and can usually be available to both generate (raise the frequency) and charge (lower the frequency).

These markets are changing[45]. New market entrants are seeking a share of the large profits that batteries have made in the last few years. Regulatory reforms are trying to keep up with the changing abilities from new technologies. There is a promise to open the market for individual 'distributed energy resources' (DER) such as hot water systems, pool pumps, household batteries, controllable solar and electric vehicles. The Energy Security Board is working on two way markets to be ready for 2025. These changes will alter the commercial opportunities for a local battery that provides value out to the wider electricity system.

- Frequency control (regulation & contingency FCAS, primary, secondary and tertiary response, frequency stability services)
- Ride-through or bridging power
- Spinning reserves
- Synthetic Inertia
- Ramping capabilities
- Smoothing of variable renewable energy
- Transmission / distribution grid stability
- Reduce load shedding

The synthesis above uses different terms from international electricity markets. The differences reflect alternative choices about how to manage contingencies. The US market references *primary frequency response* (provide frequency stability in the first 15-30 seconds and hold for up to 15 minutes), *secondary frequency response* (return frequency to normal in the first 200 seconds and hold for up to 2 hours) and *tertiary frequency response* (acting within 15 minutes to replace the reserves). *Spinning reserve* is a traditional approach where generation capacity (equivalent capacity to the largest generator in the market) was available on standby and already spinning to replace any potential failure. This approach has been largely replaced by today's FCAS markets but the market rulemaker (AEMC) is revisiting the need for reserves and the need for approaches that help the

[44] Find reference for this – don't forget about FCAS watt clarity or was it energy council about FCAS recent prices or SA report or commentary on SA report.
[45] https://www.allens.com.au/insights-news/insights/2021/06/future-revenue-opportunities-anticipated-post-2025/

market to ramp generation up and down. Changes in reliance on wind and solar means that a change in the resource (eg at sunset) affects many generators at the same time and the rate of change in the wholesale market happens at an unprecedented rate. *Ramping services* are being explored to assist at these times.

3. Power quality

Local voltage support

There are additional power quality benefits associated with matching supply and demand more effectively at the local level and managing the peaks so that they don't become constraints. At times, the export capacity on a low voltage feeder (known as hosting capacity) is constrained because the house at the end of the feeder is experiencing voltages that are too high. Energex does not have full visibility to the occurrence of high voltages because they are caused by solar exports and the energy flows toward the transformer. When high voltages occur, the protection settings on solar systems will turn the solar system off until voltages return to normal. If a local battery is designed to provide value in voltage support, the *location* of the battery along the feeder may become important, or additional investment may be needed to manage current flows and reduce voltage drops.

- Voltage support services *
- Voltage support, voltage regulation and control
- Reactive power

*Noting that the support needed varies depending on voltage and location. The battery primarily supports voltage at the point where it provides the most change to current and energy flows. The battery also supports voltage and frequency at higher voltage levels in the system as local changes also produce changes at other levels, including the whole supply /demand balance.

Many of the reports above refer to improved power quality and improved performance of the network for short duration disturbances that a battery can respond to. This needs further investigation to understand the nature of the disturbances and the investment that might be required to ensure the battery is deployed to also support power quality.

- Power quality maintenance

4. Backup supply

There are limits on the extent to which a local battery is suitable as a back up generator, particularly if it is sized to provide only 1-2hrs of energy at full capacity. Nevertheless, a battery would be a key component in a providing supply reliability and protecting loads against interruptions if a) the immediate battery vicinity is designed to disconnect from the main grid during faults and b) the battery, major loads and generation are designed to operate as a stand alone microgrid during those times.

- Emergency back up power – faults, load shedding, bushfire risk disconnections
- Black power start (at the local level)
- Energy reliability

- System security and resilience
- Business continuity support for weather impacted communities
- Reduce unserved energy (this is a network term for energy that should have been provided but wasn't due to a supply interruption)
- Fuel savings for diesel backup / reduced reliance on diesel generators
- Smoothing of variable renewable energy

5. Non-market benefits

- Increased planning flexibility
- Choice of optimisation against a variety of outcomes – eg price, carbon, simplicity
- Risk mitigation – depending on business model, energy users and energy suppliers all carry procurement and contracting risks
- End user applications and services
- Provide energy choice
- Reducing local energy storage system investor risks
- Carbon reductions
- Reduced environmental impacts from fossil fuels
- Economic outcomes – local growth, innovation, skills, product development and employment
- Community resilience
- Quality of life improvements
- Flexibly sharing power, capacity and profits

The ANU report emphasises five essential benefits that community batteries should be designed to deliver:

- fairness and equity (aiming for equity amongst PV and non-PV owners)
- trust and transparency
- hosting capacity
- local resilience
- cost-effectiveness

6. Value unlikely to be delivered by local batteries

- Seasonal and interday (eg weekly) storage
- Capacity firming for larger renewable generators
- Regulation FCAS (The steady price for regulation FCAS is lower than the wholesale energy price, reflecting the fact that a cheap generator can easily offer the ability to raise and lower its output. It is therefore unlikely that batteries would compete in this market)
- 5min FCAS and more permanent efforts to replace reserves (Reserve power has traditionally relied on standby generation such as diesel engines available at low capital cost and high operating cost)
- Standby / standing reserve and infrequently used capacity such as reserve trader arrangements
- Ancillary services targeting transients, power quality, and reactive power management at higher voltages
- Energy security and generation adequacy over longer timeframes
- Black power start (wholesale market)

12 Appendix E – Zone Substation Analysis

See additional document for graphs of performance relating to each Zone substation.

13 Appendix F – Terms of Reference for ZEN Inc. work on community batteries

The purpose of this work is to:

- Strengthen ZEN Inc's knowledge of the issues and solutions resulting from high levels of solar penetration in Noosa
- Inform and strengthen ZEN Inc's strategic direction from 2021 – 2023
- Strengthen ZEN Inc's capacity to inform and engage with the community about the emerging issues, potential solutions and next steps to achieve the Net Zero Emissions target by 2026.

ZEN Inc will provide asap an information pack of relevant research to this work such as:

A. Useful contacts
B. Relevant data
C. Presentations about ZEN Inc's work, including videos of EV expos

A. Briefly outline the reasons why we need this research

- Having local export constraint issues in the Noosa Shire and at State & National level
- Assisting grid reliability & stability in the Noosa Shire
- Continuing to encourage Noosa business and households to take up solar
- Continuing Noosa's leadership role in reaching net zero emissions by 2026
- Anticipating emerging issues e.g. more solar is being generated in some areas than there is demand in these areas; changing demand as a result of EV take up
- Outlining the economic e.g. $77million staying in Noosa Shire; social and environmental benefits of solar uptake

Please note: These points only need a paragraph per point. It will provide background to the wider reading audience about why this work is being undertaken.

B. Document the emerging issues

- Document emerging issues in the Noosa Shire area and in Qld

C. Potential Solutions should include

- Research and documenting the existing and proposed battery storage systems (behind and in front of the meter) across Australia, with greater focus on Energy Qld's batteries, and including ARENA community battery studies
- Demonstrate how battery solutions could apply to the Noosa Region – Noosa Shire

Please note: ZEN Inc. would like Noosa to be the first trial battery site in the Energex service area.

Please Note: Microgrids **are not** part of the scope of this investigation

D. Engage with Energex (in partnership with ZEN Inc and Noosa Council)

- Exploratory meeting(s) about potential solutions and local circumstances

Please note: This should be done during this work to demonstrate to Energex that ZEN Inc. is prepared to work with them on solutions.

E. Recommendation of solution(s)

- Provide a pre-feasibility business case for the recommended solution(s)

F. Business Case development

G. Deliverables

- Draft outline of report **by 29th June 2021**
- Final Report, following review by ZEN Inc., possibly by end of third week in July, with the timeline to be confirmed **on Wed. June 23.**

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