Opportunities for Utility Scale Battery Storage in NSW

A report by the Australian Energy Storage Alliance in partnership with AECOM and supported by the NSW Energy and Resources Knowledge Hub through the NSW Department of Industry.

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Contents

Executive Summary

NSW has the highest and also the fastest growing population in Australia. It also contributes the most electricity generation capacity to the National Electricity Market (NEM); however, relatively high fuel costs typically make it a net importer of electricity from the NEM. Tightening supply arising from the closure of a significant coal fired plant has coincided with a resurgence of peak demand in NSW. In response, NSW has experienced one of the steepest rising wholesale electricity price paths across the NEM. More thermal retirements are on the horizon, with AGL Energy's plan to retire its 2000 MW Liddell plant in NSW in 2022.

Council of Australian Governments (COAG) is the peak intergovernmental forum in Australia whose role is to initiate, develop and monitor the implementation of policy reforms that are of national significance and which require cooperative action by federal, state and territory governments. The COAG Energy Council coordinates government energy policy. The Energy Security Board, reporting to the COAG Energy Council, is comprised of an Independent Chair, Independent Deputy Chair and the most senior leaders of the:

1. Australian Energy Market Operator (AEMO)
2. Australian Energy Market Commission (AEMC)
3. Australian Energy Regulator (AER)

It is responsible for the implementation of the recommendations from the Independent Review into the Future Security of the National Electricity Market (Finkel Review). The Finkel Review provided a plan to maintain security and reliability in the NEM in light of significant transition, including rapid technological change. The Finkel Review describes the need for four key outcomes for the NEM: increased security, future reliability, rewarding customers and lower emissions. The report discusses how security and reliability have been compromised by poorly integrated variable renewable energy, including wind and solar, coincided with the unplanned withdrawal of older coal and gas-fired generators.

For a power system to operate reliably, it is important that sufficient generation capacity is available to meet demand at any point in time. The requirement for dispatchable capacity is becoming more prominent as non-dispatchable variable renewable energy sources such as wind and solar increase its share in the generation mix. Utility-scale battery storage is widely viewed as being a key enabling technology that is likely to play a critical role in ensuring the provision of a secure and reliable electricity system in a future of high penetration variable renewable energy.

Regulatory parameters and processes for utility scale battery storage are uncertain; AEMO is investigating their security and reliability service potential and has interim arrangements to assess the conditions for connection, registration and operation of battery energy systems on a case-by-case basis in accordance with the National Energy Rules (NER). Given the inexperience in dealing with utility scale battery storage projects, there is concern that the grid connection process will be onerous for utility scale battery storage projects leading to project delays. States such as South Australia and Victoria have supported pilot installations, which are expected to provide input into these processes with the outcome of reducing the burden on developers.

Currently, there is no utility scale battery storage connected in NSW. Utility-scale battery storage in NSW has the potential to provide numerous opportunities in demand management, network support, generation support, ancillary services, market trading and strengthening the NSW economy.

As a technology, utility scale battery storage is still in its infancy. Historically, there has been little demand for utility scale battery storage functionality and capital costs have been prohibitively expensive. Despite the emergence of a number of commercial and technical drivers, there are many challenges that are slowing the commercialisation of utility scale battery storage projects in Australia.

Looking forward

The future role of batteries in the NEM will largely be determined by the extent and efficacy of efforts made to address the technical, commercial and regulatory risks. The rate of retirement of thermal generation capacity, will also largely impact the future penetration rate of utility scale battery storage.

Most of NSW's development approvals for solar or wind farms recently lodged include the potential for future installation of utility scale battery storage, in anticipation that these risks will be addressed.

A pilot undertaken at scale in NSW would provide knowledge sharing and lessons learnt, in a similar manner to the utility scale battery storage projects instigated and funded by the SA, QLD, and VIC State Governments and the Australian Renewable Energy Agency .

Social trends that result in increased peak energy demand provide the greatest opportunities for utility scale battery storage. These trends are likely to include the electrification of transport and other industries, digitalisation increasing the demand at data centres and decentralisation of utilities in a way that decreases coordination and control.

With further development of long duration utility scale battery storage and other innovative technologies, together with more implementation, the choice of the type of utility battery storage system is widened, leading to lower costs across all battery types.

Developers have an interest in utility scale battery storage in NSW; however, this is still early days and lower cost of batteries would be one element to make the economic proposition more viable. Utility scale battery storage costs remain high compared to most other technologies but have decreased in recent years. The declining cost path is expected to continue.

With strong interest in further projects, some State Governments and the Australian Renewable Energy Agency have provided funding for pilot projects. In South Australia, the state government has contracted network support services from the Hornsdale Power Reserve utility scale battery storage system. The Australian Renewable Energy Agency and Victorian State Government have jointly funded the rollout of two utility scale battery storage projects in Victoria. The Queensland state Government is conducting a reverse auction for up to 100MW of energy storage, which is likely to include utility-scale battery storage.

There are currently many initiatives underway in the market that are highly relevant to the role of utility scale battery storage. These include the Finkel Review (refer to section 1.2), AEMC's System Security Market Frameworks Review and AEMO's Future Power Systems Security Program (which together considered the fast frequency response and inertia ancillary services proposals), state-based funding auction programs and the ongoing development of the National Energy Guarantee.

The results of these programs are likely to have a large impact on the role of utility scale battery storage and its financial drivers. Some of the proposed changes are likely to drive investment in utility scale battery storage, or even assist the business case. However, until these changes are implemented, the possibility of regulatory change brings uncertainty to the business case.

This report is a snapshot of the current market situation as understood at May 2018 and is expected to have revisions in the future. It currently does not include content on energy storage options other than utility scale battery storage, and the AESA recognises that this is an area for a future report. Please contact the Australian Energy Storage Alliance at info@energystoragealliance.com.au to obtain a copy of any later released version.

Glossary

Term	Definition
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AESA	Australian Energy Storage Alliance
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
CEFC	Clean Energy Finance Corporation
DMIS	Demand Management Incentive Scheme
DNSP	Distribution Network Service Provider
ESS	Energy Storage System
EV	Electric Vehicle
FCAS	Frequency Control Ancillary Market
FFR	Fast Frequency Response
Finkel Review	A report led by Australia's Chief Scientist Dr Alan Finkel titled: Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future.
GW	Gigawatt
kW	Kilowatt
LGC	Large-scale Generation Certificate
MW	Megawatt
NEM	National Electricity Market
NSP	Network Service Provider
PPA	Power Purchasing Agreement
SCADA	Supervisory Control and Data Acquisition
SRAS	System Restart Ancillary Service
STATCOM	Static Synchronous Compensator
SVC	Static Var Compensator
TNSP	Transmission Network Service Provider
Utility / Utility Scale	Grid connected at scale (>5MW)

Foreword

This report was jointly prepared by AECOM and the Australian Energy Storage Alliance (AESA), its members, and industry stakeholders in 2018. It presents an overview of the opportunities for utility scale grid connected battery storage systems in NSW. It is based on AESA's and AECOM's industry knowledge and experience, desktop research, and consultation with a wide group of industry representatives, including project proponents, market administrators, technology providers and other market experts. It discusses broad technical and commercial principles only and should not form the basis of investment decisions.

1.0 Overview of the NSW Electricity Market

NSW has the highest population of any state in Australia, with almost 8 million residents, roughly 62% of whom live in Greater Sydney [1]. NSW also has the fastest growing population in Australia, with a growth rate of approximately 106,000 people annually [1]. It also contributes the most electricity generation capacity to the National Electricity Market (NEM), of each of the five physically interconnected regional market jurisdictions.

NSW has relatively high fuel costs, typically making it a net importer of electricity from the NEM [2]. Tightening supply arising from the closure of a significant coal fired plant has coincided with a resurgence of peak demand in NSW. In response, NSW has experienced one of the steepest rising wholesale electricity price paths across the NEM [2]. More thermal retirements are on the horizon, most significantly AGL Energy's plan to retire its 2000 MW Liddell plant in NSW in 2022 [2].

1.1 The NEM

The NEM is a wholesale spot market into which over 300 generators across five Australian regions – Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia and Tasmania - sell electricity. Changes in electricity supply and demand determine the electricity spot price, with the lowest cost generation scheduled by the Australian Energy Market Operator (AEMO) to meet demand every five minutes. The NEM's transmission and distribution grid moves this power throughout the five regions to service almost 10 million residential, commercial and industrial energy users.

1.1.1 Market Bodies

The Council of Australian Governments (COAG) is the peak intergovernmental forum in Australia whose role is to initiate, develop and monitor the implementation of policy reforms that are of national significance and which require cooperative action by federal, state and territory governments [3].

COAG created the governance structure shown in Figure 1, including three market bodies, to oversee Australia's energy market:

1. **Australian Energy Market Operator (AEMO):** is responsible for the day-to-day management of the wholesale and retail energy market operations [3]. Specifically, one of the core functions of AEMO is to maintain and improve power system security and coordinating the strategic development of the national electricity grid and long term gas infrastructure and resource management.
2. **Australian Energy Market Commission (AEMC):** as the rule maker for the Australian electricity and gas markets, the AEMC makes and amends the National Electricity Rules, National Gas Rules and the National Energy Retail Rules. The AEMC also provides market development advice to governments [4].
3. **Australian Energy Regulator (AER):** is the regulator of the wholesale electricity and gas markets in Australia. It forms part of the Australian Competition and Consumer Commission (ACCC) and enforces the rules established by the AEMC. A specific function includes setting maximum prices that energy network owners can charge [3].

The AEMC is accountable to the COAG Energy Council which reports to COAG. The COAG Energy Council is chaired by the Commonwealth Energy Minister and its members include all state and territory energy ministers. It coordinates government energy policy.

The Energy Security Board is comprised of an Independent Chair, Independent Deputy Chair and the most senior leaders of the AEMO, AEMC and AER. It is responsible for the implementation of the recommendations from the Independent Review into the Future Security of the National Electricity Market (Finkel Review). The Finkel Review provided a plan to maintain security and reliability in the NEM in light of significant transition, including rapid technological change [5].

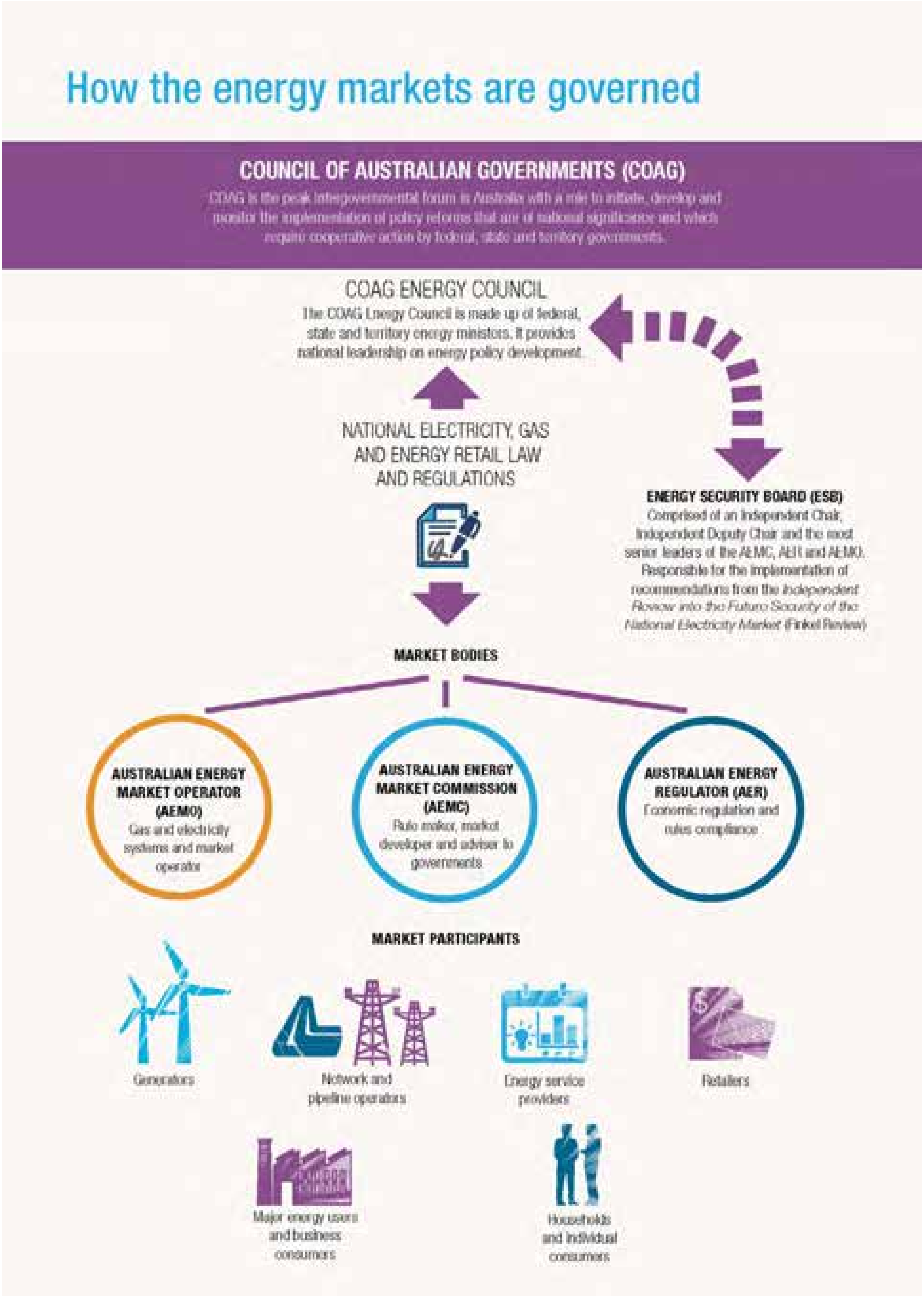


Figure 1: Market bodies
Source: [3]

1.2 Secure and reliable supply

The Finkel Review [6] describes the need for four key outcomes for the NEM: increased security, future reliability, rewarding customers and lower emissions. These outcomes are underpinned by the three pillars of an orderly transition, better system planning and stronger governance.

The report discusses how security and reliability have been compromised by poorly integrated variable renewable energy, including wind and solar, coincided with the unplanned withdrawal of older coal and gas-fired generators.

The Finkel Report specifically lists ways to increase security in the NEM, including:

1. Imposing and enforcing obligations on new generators to provide essential security services that contribute to fast frequency response and system strength.
2. More conservative operation in each region through maintaining system inertia and tighter frequency control, to make it better able to withstand disruptions like generator outages or interconnector failures.

The Finkel Report lists ways to increase future reliability, including:

1. Placing obligations on new generators to ensure adequate dispatchable capacity in all regions, which can be met using a variety of technologies or partnership solutions.
2. Incentivising new generators to enter the market.

Utility-scale battery storage is widely viewed as being a key enabling technology that is likely to play a critical role in ensuring the provision of a secure and reliable electricity system in a future of high penetration of variable renewable energy.

The Finkel Review [6] defines system security and reliability as:

System security
Security is a measure of the ability of the power system to tolerate disturbances and maintain electricity supply to consumers. Security is achieved by operating the system in a satisfactory and stable operating state and within the required bounds of a number of technical parameters such as frequency, voltage, fault current levels, and the operation of equipment within its design limits. For example, the unexpected disconnection of a large generator or load can cause frequency deviations outside the normal range, leading to a rapid rate of change of frequency and resulting power system instability. This can then lead to cascading failures and ultimately even a "black system" where a significant part of the power system experiences a failure of the electricity supply.

Reliability
Reliability is a measure of the ability of generation and transmission capacity to meet consumer demand. Having adequate supply to match demand at all times raises new challenges and opportunities in a future with high proportions of variable renewable energy generators, and where generation and storage is distributed rather than centrally dispatched. Reliability is quantified as the proportion of total electricity demand that is not delivered. A secure power system is a necessary, but not sufficient, condition for reliability

1.3 Current generation in NSW

For a power system to operate reliably, it is important that sufficient generation capacity is available to meet demand at any point in time. The requirement for dispatchable capacity in the form of energy storage is becoming more prominent as non-dispatchable variable renewable energy sources such as wind and solar increase its share in the generation mix.

Despite the recent surge in investment in renewable generation, coal fired generation remains the dominant supply technology in the NEM, accounting for 52 per cent of registered capacity and supplying 76 per cent of output in 2015–16 [7].

The different regions belonging to the NEM display different generation capacity sizes and fuel type compositions, as shown in Figure 2. The generation mix for each region is largely reflective of the availability of different natural resources in each region. NSW's registered capacity stands above all other NEM regions and is dominated by black coal.

The privatisation of state owned generation businesses was completed in 2015. As a result, private entities own most generation capacity in NSW. AGL Energy (29 per cent), Origin Energy (23 per cent) and Snowy Hydro (19 per cent) emerged as the state's leading generators. [7]

While utility scale solar farms have been slow to develop in Australia (due to its relatively high cost historically) deployment is rapidly accelerating as a result of significant cost reductions in recent times. NSW has lead the way with close to 300 MW of solar capacity installed in NSW to date.

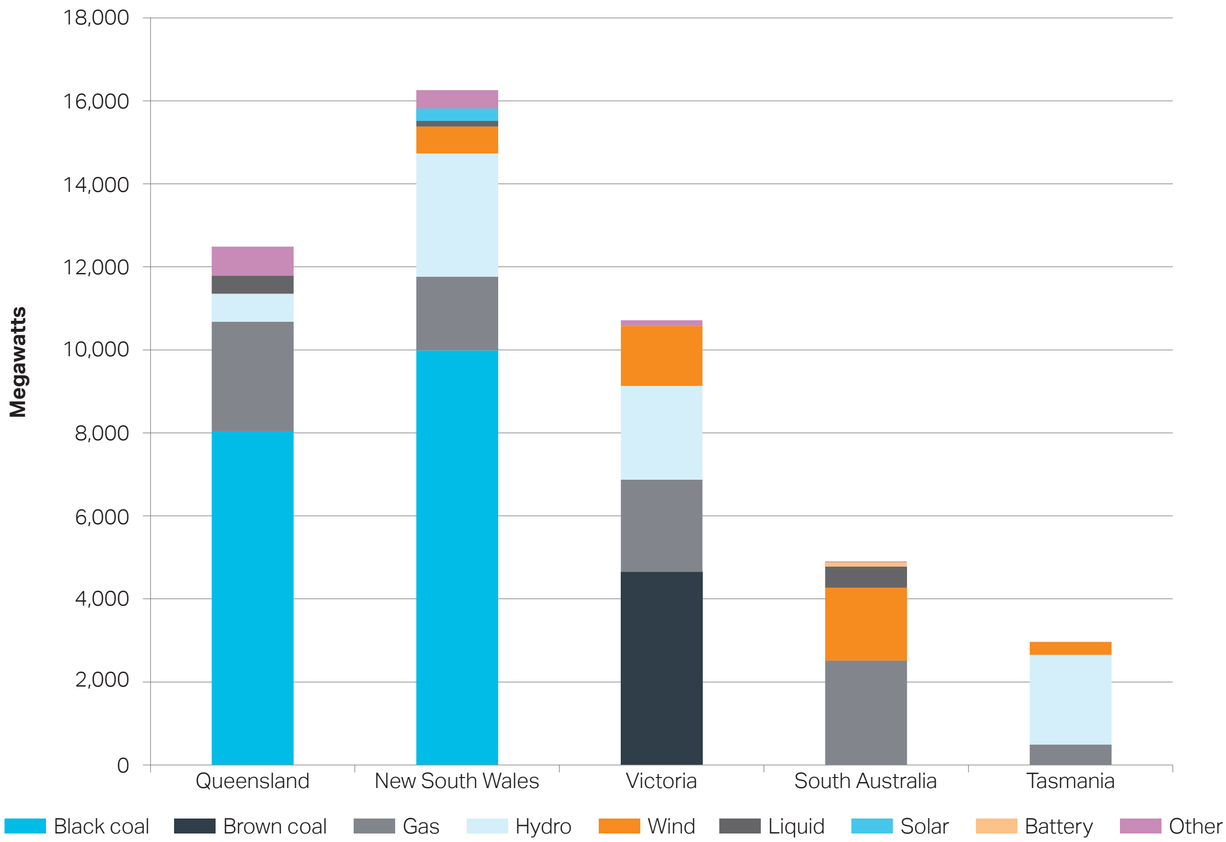


Figure 2: Registered capacity per NEM region per fuel source [8]

Expected life spans of generation in NSW, as an indicator of when plant retirements will occur, shows that there will be a need for 8640 MW of new capacity to replace thermal plant, as indicated in Table 1. There is 1,167 MW of wind and solar under constructions and a further 12,376 MW planned as shown in Table 2. For further details refer to Appendix A.

Table 1: Current coal, wind and solar generation in NSW [9]

Plant	Size (MW)	Type	Location	Expected closure
Bayswater	2,640	Coal	Muswellbrook	2030
Eraring	2,880	Coal	Dora Creek	2030
Liddell	2,000	Coal	Muswellbrook	2022
Mt Piper	1,400	Coal	Blackman's Flat	
Vales Point	1,120	Coal	Mannering Park	2030
Boco Rock Wind Farm	270	Wind	Nimmitabel	
Capital Wind Farm	132	Wind	Bungendore	
Cullerin Range Wind Farm	30	Wind	Gunning	
Gullen Range Wind Farm	165.5	Wind	Bannister	
Gunning Wind Farm	46.5	Wind	Gunning	
Taralga Wind Farm	100	Wind	Taralga	
White Rock Wind Farm	48.3	Wind	Glen Innes	
Woodlawn Wind Farm	48.3	Wind	Tarago	
Broken Hill Solar Plant	53	Solar	Broken Hill	
Griffith Solar Farm	25	Solar	Yooglai	
Gullen Range Solar Farm	10	Solar	Bannister	
Moree Solar Farm	56	Solar	Moree	
Nyngan Solar Plant	102	Solar	Nyngan	
Parkes	50.6	Solar	Parkes	

Table 2: Table 2 Planned wind and solar in NSW [9]

Phase	Type	Quantity	Size (MW)
Under construction	Wind	4	901
Under construction	Solar	5	266
Planned	Wind	17	4,165
Planned	Solar	50	8,211

1.4 Regulatory parameters and processes

AEMO is investigating the security and reliability service potential of utility scale battery storage, given the National Electricity Rules (NER) can accommodate batteries and other energy storage providers but it is not always clear how. AEMO has received enquiries from proponents of utility scale battery storage projects, requesting information relevant to the installation of both standalone battery systems, as well as systems installed with new or existing generation. In the short term, while the 12 month investigation continues, AEMO is assessing the conditions for connection, registration and operation of battery energy systems on a case-by-case basis in accordance with the NER.

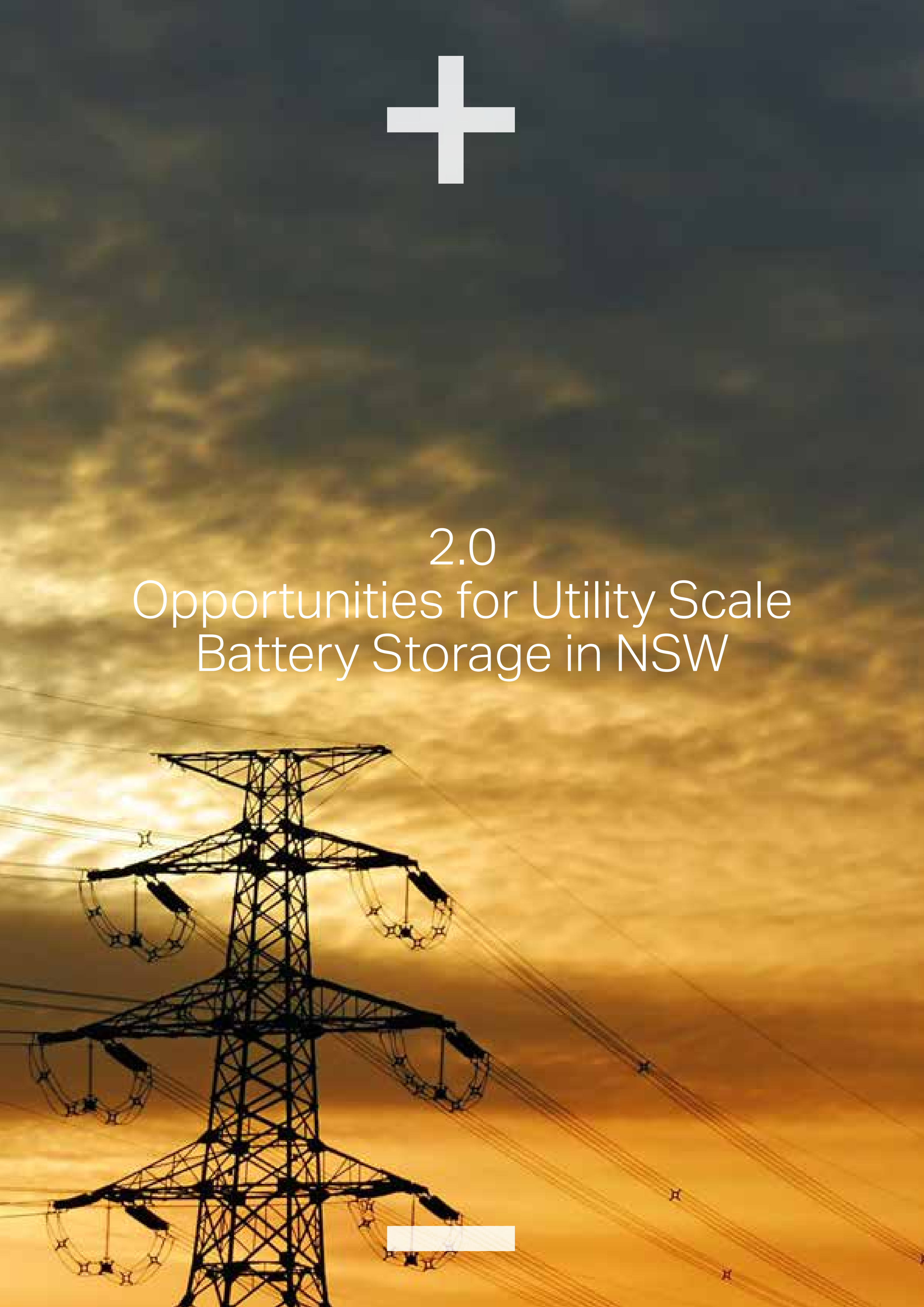
The interim arrangements to inform review of the NER framework applying to energy storage cover six broad areas, key considerations for which include:

1. Registration
2. Metering
3. SCADA and data collection
4. Performance standards
5. Transmission use of system and Distribution use of system charges
6. Participation in ancillary services markets.

For further details refer to Appendix B.

Given the inexperience in dealing with utility scale battery storage projects, there is concern that the grid connection process will be onerous for utility scale battery storage projects leading to project delays. This is largely because AEMO and NSPs need to familiarise themselves with the technology, its impact on power systems, and to determine appropriate connection requirements. Utility scale battery storage is challenging for system planners due to potential to drive large swings in power flow over very short times. Both AEMO and NSPs take a conservative approach to grid connection out of necessity. It is highly important that utility scale battery storage is installed to improve the reliability and security of the grid rather than weaken it. An important question, which developers and network service providers need to consider, is where to locate the utility scale battery storage system: at the source of generation or at the load.

States such as South Australia and Victoria have supported pilot installations, which are expected to provide input into these processes with the outcome of reducing the burden on developers.



2.0 Opportunities for Utility Scale Battery Storage in NSW

While variable renewable energy generation, including wind and solar, currently provide the cheapest form of electricity, there are limitations in their ability to support the performance requirements of the electricity system such as frequency stability, system strength and dispatchable capacity. Utility scale battery storage can facilitate the transition to higher penetrations of variable renewable energy generation by contributing to the provision of these essential system requirements.

Lachlan Blackhall of ANU commented that:

"There is increasing adoption of utility scale battery storage, often installed alongside utility scale wind and solar farms around Australia. The most prominent example of a utility scale battery system is the 2017 installation of the 100MW/129MWh Hornsdale Power Reserve (HPR) in South Australia.

Alongside other utility scale battery storage deployments that are occurring around Australia throughout 2018, there is an increasing awareness of the role that utility scale battery storage will play in providing energy security services to the operation of the National Electricity Market (NEM). This has been best demonstrated by HPR which, as of May 2018, has already taken a 55 per cent share in the South Australian frequency and ancillary services market, and lowered prices in that market by 90 per cent [10].

The opportunities for, and economics of, utility scale battery storage are still being fully investigated, particularly when such systems are collocated with utility scale wind and solar farms. The value of these battery systems will in many cases be driven by the participant categories, operating rules, and available exemptions for market participation as defined by The Australian Energy Market Operator (AEMO)."

2.1 Current utility scale battery storage in NSW

Currently, there is no utility scale battery storage connected in NSW. Examples of grid connected systems are small in scale and are generally used for back-up power rather than generation capacity or grid support. CWP Renewables, a developer of renewable energy projects in Europe and Australia, is proposing to add grid scale battery storage to their site near Glen Innes in NSW alongside the almost completed 270MW Sapphire Wind Farm. This project, envisioned as a solar plus wind plus battery combination, will be part of a 1.3GW portfolio of projects called the GrassRoots Renewable Energy Platform. At Sapphire, it will include the construction of a new 230MW Sapphire Solar Farm and a new 75MWh utility level battery system, alongside the 270MW Sapphire Wind Farm; all components should be completed within a two year timeframe.

Andrew Thomson of CWP added that this platform is expected to provide a more desirable option for commercial and industrial (C&I) clients. The economics for batteries are taking shape, CWP sees the main driver for this type of project is the dispatchability of renewable power and matching generation to customers' unique load profiles. The additional benefit from such sites will derive from utility level batteries being further recognised and valued by the regulatory market, as the market transitions away from fossil-fuelled electricity sourced from existing coal-fired generators.

Michael Gartner, Managing Director of Photon Energy Australia, commented:

"Photon Energy installed the first grid connected battery storage system in NSW, a small system for hybrid backup alongside a PV solar system for powering the BAI radio broadcast towers of Muswellbrook, NSW" [11]

The company now plans to *"develop eight solar PV farms with grid scale battery storage in NSW and is at the development approval stage for the first of these projects." Michael would like to see "a market for capacity and ancillary services to support these initiatives"*. He added, *"bi-lateral agreements, similar to Power Purchase Agreements (PPAs) are needed to proceed with these new sites, and it would be helpful if there is a mechanism for the market to value capacity."*

Michael added that *"adding battery storage is a risk for developers. It is critical for developers to be adequately compensated for installing grid-scale battery storage alongside renewable energy projects, and to be compensated on-going for the services provided by the battery."*

2.2 Services that can be provided by battery storage

Utility scale battery storage can provide a wide range of services that yield technical, commercial and economic value. These services can be categorised into four high level functions, as shown in Figure 3.

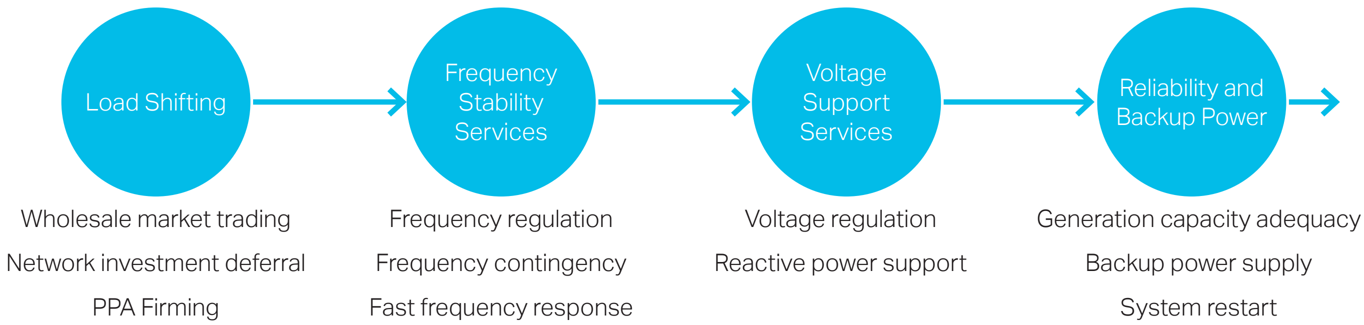


Figure 3: Overview of utility scale battery storage services

2.3 Opportunities

The services provided by batteries provide numerous opportunities to a large range of beneficiaries.

2.3.1 Demand management

Beneficiaries: AEMO, NSP, Community

How: Transmission and Distribution (T&D) investment deferral, generation capacity adequacy

Transmission and Distribution (T&D) investment deferral: utility scale battery storage can reduce peak demand on T&D network assets through load shifting from times of peak demand to times of lower demand, which is aggravated by the development of renewable energy projects in areas where the network is weak. This can be valuable if a network asset requires augmentation to accommodate increasing demand. If the utility scale battery storage can defer the augmentation, considerable value can be derived by avoiding the financing and depreciation costs that would otherwise be incurred to increase the capacity of the network. Among other incentives, the Demand Management Incentive Scheme (DMIS) can provide a financial incentive for network businesses to pursue utility scale battery storage as a means to defer investment. The annualised value of investment deferral is highly variable, but AECOM estimates that it is typically in the order of $45-$120/kW of the available capacity at the time of peak demand.

Ausgrid is the largest distributor of electricity on Australia's east coast, providing power to 1.7 million households and businesses across 22,000 square kilometres covering Sydney, the Central Coast and the Hunter Valley. The Ausgrid Regulatory Proposal 2019-24 sets out how much the business needs to invest in the next five years and includes this comment:

"Today, new technologies have given us better ways to handle peak demand periods. A smart grid and smart devices can make it easier for customers to use less energy at peak times and use solar panels and batteries to support the grid during the peak." [12]

Ausgrid currently have a number of grid battery demonstration projects in the pipeline. The first will be a community shared battery demonstration project, most likely deployed in a brownfield scenario where we already have high solar penetration. Another is a rural microgrid project including a grid scale battery that will demonstrate the ability to use microgrid islanding to mitigate bushfire risk.

Junayd Hollis, Head of Strategy at Ausgrid noted that *"one of the key opportunities surrounds unlocking the value of communal solar and storage assets. While behind the meter applications of these technologies are increasingly being adopted, communal assets have been slow to materialise as there are significant regulatory barriers that need to be addressed in order for all our customers to realise the full potential benefits of these technologies."*

Mr Hollis added that *"a key area of change for Ausgrid lies in reforming tariffs, developing cost reflective network pricing that is equitable, puts all forms of renewable generation and storage technology applications on a level playing field, and encourages the most cost effective forms of decarbonisation".*

Essential Energy, an electricity infrastructure company which maintains the electrical distribution networks for 95% by landmass of New South Wales, is currently undertaking an the Australian Renewable Energy Agency (ARENA) supported pilot of aggregated customer owned battery storage systems with several partners. Through the project, labelled Networks Renewed, Essential Energy aims to develop a set of guidelines for future uptake to ensure such technology is optimally integrated and explore the possible value such technology can provide on a least cost basis to address network constraints. Currently, there is no utility scale BESS on the Essential Energy network, however the number of queries/level of interest relating to the connection of large scale battery storage is increasing [13].

Generation capacity adequacy: utility scale battery storage can provide dispatchable generation capacity to the system. However, their contribution is limited by the battery's state of charge and the energy storage capacity. To provide a meaningful contribution to generation capacity adequacy, it is important for the battery to have multiple hours of discharge capability.

2.3.2 Network support

Beneficiaries: NSP, Community

How: Voltage support services, back-up power

Voltage support services: utility scale battery storage can play a role in managing voltage on networks, through voltage regulation of both voltage drop and voltage rise.

Voltage drops over the length of the long 'skinny' power lines, particularly distribution lines with lower voltage or large loads. Batteries can reduce the level of voltage drop by reducing peak demand (as the voltage drop is proportional to the demand).

In areas of the distribution network where large amounts of (largely solar PV) distributed generation have been installed, local voltages on the distribution network can rise above acceptable levels and, in some cases, result in reverse flow through the distribution system. Reverse flow can cause issues in protection systems not designed for two way flow. It can also cause solar inverters to disconnect from the grid if the voltage rises too much. In these instances, batteries can be used to reduce voltage rise problems by storing excess solar generation locally. However, it is noted that this function is more regularly associated with smaller, behind-the-meter batteries rather than utility scale battery storage.

While utility scale battery storage can also provide reactive power support to assist NSPs to stabilise the grid, improve power factor and reduce voltage drops over long power lines, there are considerably cheaper alternatives for this use (e.g. STATCOM, SVC).

Backup power – short term islanding: utility scale battery storage can be used for back-up power in parts of the grid that have poor reliability. In particular, utility scale battery storage can be used to facilitate islanding customers, separating them from the fault and providing power while the fault is resolved. While utility scale battery storage cannot protect against all outage risks, there is significant potential to reduce unserved energy that occurs upstream of regional substations. However, it is important to note that this revenue stream is highly site-specific and subject to regulatory scrutiny by the AER.

2.3.3 Generation support

Beneficiaries: Generator, Developer

How: Reactive power support and prevention of curtailment

Reactive power support: The provision of reactive power is a normal performance standard requirement for generators in the NEM (without financial compensation). Where a generator requires reactive power support, battery inverters typically have 'four quadrant' capability, which means they have the ability to provide and absorb reactive power support to the network.

Prevention of curtailment: Batteries can address issues such as generation intermittency, grid strength and stability and supply adequacy. They can provide a cost-effective option to address such issues and allow variable renewable energy to provide a greater share of Australia's electricity needs.

TransGrid commented on curtailment:

"TransGrid is the operator and manager of the high voltage transmission network connecting electricity generators, distributors and major end users in New South Wales and the Australian Capital Territory. TransGrid's network is also interconnected to Queensland and Victoria, and is instrumental to an electricity system that allows for interstate energy trading.

Developers and generators take on the curtailment risk under the current 'open access' arrangements. The current NEM framework is one where generators bear the risk that there is insufficient capacity on the shared network such that their output becomes constrained, either when they first connect to the network, or through time as the result of load growth and the location decisions of future generators. That is, the NEM framework is not one in which generators receive 'firm' access to the shared transmission network as a consequence of their connection agreement with the TNSP.

Connection agreements may include emergency access constraints including tripping and runback. Under a transfer tripping scheme, the generation asset will be instantaneously disconnected following the trip of a transmission line. Under a runback scheme generation is automatically reduced following transmission contingencies (trips) where loadings may exceed the contingency ratings of any of the remaining transmission lines. The runback will continue to operate and dispatched generation will be reduced until the transmission loadings are brought below their contingency ratings.

For the NSW transmission network, we have significant connection interest from renewables in zones that have limited network capacity remaining. TransGrid's ISP submission [14] (page 22 and reproduced in Figure 4) shows the relative connection interest and network capacity remaining for those zones. Zones with little or no capacity remaining are likely to experience congestion in some scenarios, without additional investment."

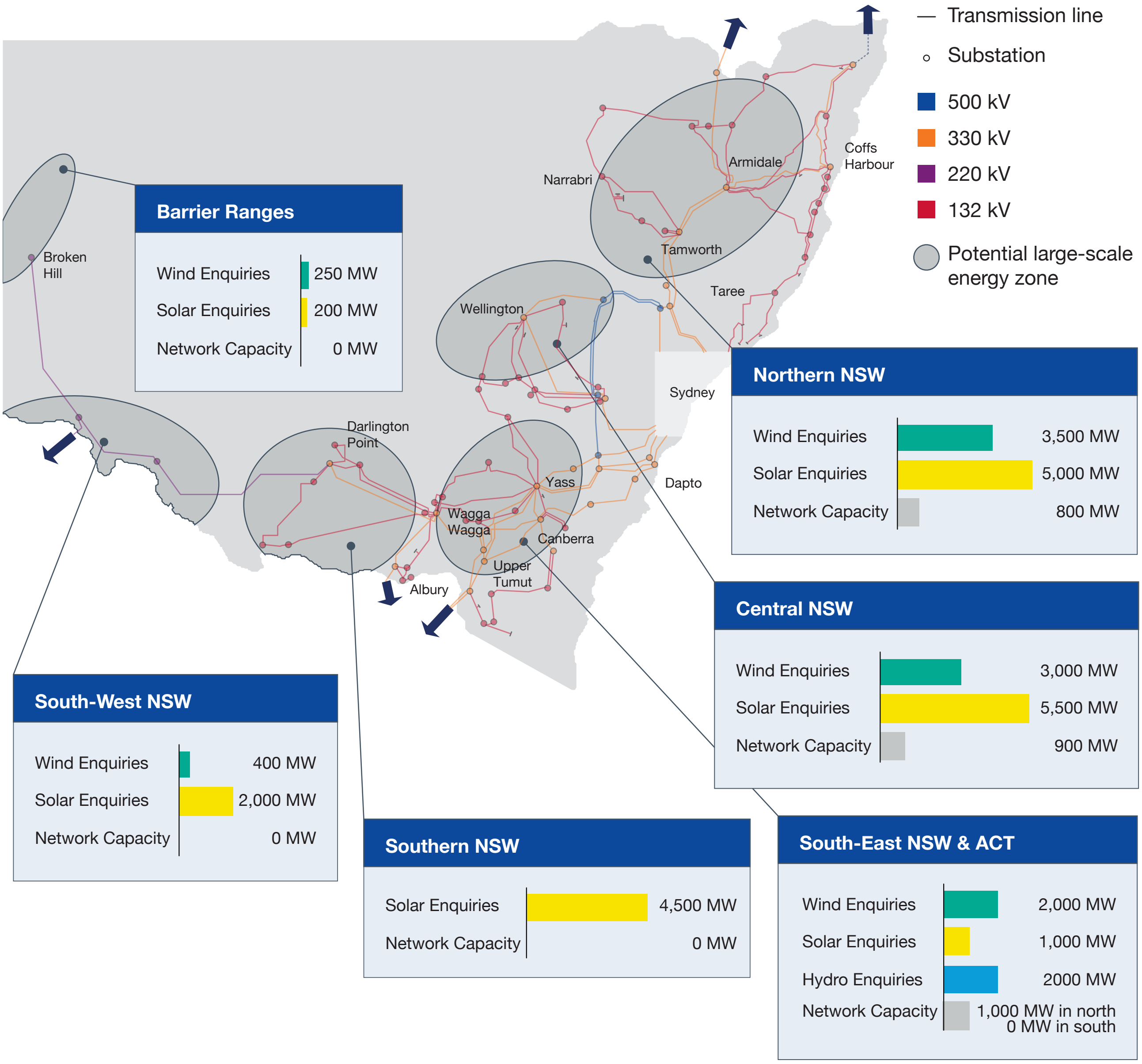


Figure 4: Current connection enquiries to TransGrid network [14]

2.3.4 Ancillary services

Beneficiaries: AEMO, Battery operator

How: Frequency control and stability, System Restart Ancillary Services

Frequency control and stability: utility scale battery storage can generate revenue by participation in the Frequency Control Ancillary Services (FCAS) markets. These services can be broken down into three sub-categories:

1. **Frequency Regulation:** ensures that the supply and demand of electricity remains balanced, and that the system frequency is maintained. This is achieved by AEMO issuing signals to FCAS regulation service providers, instructing them on how they need to respond to maintain the system frequency. Currently, the expected revenue from providing FCAS regulation services is highly inflated, compared to historical averages. However, developers targeting FCAS regulation services are vulnerable to competition from new entrants, and therefore face a large amount of revenue risk. This creates 'bankability' issues for utility scale battery storage developers.
2. **Frequency Contingency:** ensures that sufficient 'reserve' system flexibility is available to maintain system security following credible contingency events. There are six contingency markets: 6 second response, 60 second response and 5 minute response, for both raising and lowering the system frequency. Utility scale battery storage can bid into all six of these services simultaneously (assuming there is enough 'head room'). It can also provide faster response time and ramp rates that facilitate a faster stabilisation of grid frequency than traditional providers of contingency services. However, FCAS contingency services are not frequently dispatched as contingency events are relatively uncommon.
3. **Fast Frequency Response (FFR):** is effectively a faster version of the FCAS contingency services that acts over a fraction of a second. There is currently no formal market, and therefore revenue, available for this service. As such, there is no incentive for market participants to offer this service. However, the AEMC has raised the possibility of introducing a market for FFR, as part of its Frequency Frameworks Review

There are more generators in NSW than in states such as South Australia, and therefore less volatility of FCAS which means less potential revenue.

Systems Restart Ancillary Services (SRAS): utility scale battery storage can provide auxiliary power to help other generators, with sufficient system strength, to restart following a blackout. AEMO procures this service for three year periods via a tender process. It pays for both for availability of the service and for delivery of the service. Given the low frequency of system restarts required, the majority of the funding is delivered through the availability payment. It is estimated that a battery would need to have at least 5MW discharge capability and at least one hour of storage available at all times to provide this service. Historically, there has been limited competition in the provision of SRAS services, with prices increasing substantially following the volatility of wholesale markets in 2017.

Case Study: Hornsdale Power Reserve

"Operation of the HPR to date suggests that it can provide a range of valuable power system services, including rapid, accurate frequency response and control.

The funding arrangements for the HPR meant there was a focus on ensuring all its capabilities were fully utilised to maximise power system security for South Australia. This included engagement with AEMO when control settings and operating arrangements were determined, in a way that would not typically occur for other generation development (where the project developer is responding to existing market signals and arrangements).

Future development of batteries outside of South Australia might not result in the provision of similar services, due to the way FCAS are currently quantified and rewarded, as well as the voluntary nature of participation in the FCAS market, and in frequency control arrangements more broadly.

Where other large batteries are established under government incentive schemes, there could be a role for a more prescriptive provision of system security services, to maximise the benefits to the power system such devices can provide.

Current FCAS market arrangements could also be modified to specifically recognise the rapid and accurate response capabilities of batteries, and therefore enhance their ability to earn income from providing them" [15]

2.3.5 Market trading

Beneficiaries: Generator, Battery operator, Retailer

How: Wholesale market trading, Power Purchasing Agreements

Wholesale market trading: utility scale battery storage can be used to shift electricity from periods of low market value to periods of high market value. This function is particularly pertinent for markets with high penetrations of variable renewable energy generation, given it can help prevent spillage of excess renewable generation by storing it and shifting it to periods of higher demand or lower variable renewable energy output. For a one hour battery, annual revenue from this application has historically varied between $30-$130/kWh of storage capacity (with a high degree of variability depending on region and year). By providing added flexibility in interactions with the grid, utility scale battery storage also mitigates against curtailment risk.

Power Purchasing Agreements (PPAs): Corporate PPAs for wind and solar are a growing trend in Australia. Utility-scale battery storage can play a role in increasing the value of PPAs by firming or increasing the dispatchability of the power that is contracted. This capability may be of particular value to corporates entering into corporate PPAs to hedge against rising electricity prices under their retail supply agreements.

Baker & McKenzie's report, The Rise of Corporate PPAs 2.0 [16] summarizes the growing trend of corporate entities entering into renewable power purchase agreements.

"In Australia, a number of corporate PPAs have been signed within the last year, whereas prior to that corporate PPAs were generally just a theoretical concept. For instance, telecommunications and media company Telstra signed two corporate PPAs in 2017: it agreed to buy the output of a new 70MW solar farm near Emerald in Queensland, and then led a consortium comprising ANZ, Coca-Cola Amatil, Telstra and the University of Melbourne to enter into a PPA for the 226MW first stage of the Murra Warra Wind Farm in western Victoria. New players who are seeking to corner the corporate PPA market are also emerging. For example, Flow Power, a wholesale retailer, has created an innovative model to support corporate PPAs under which it plays a role as intermediary."

The University of NSW (UNSW) recently reached an agreement with Maoneng Australia and Origin Energy to have 100% of its energy supplied by photovoltaic solar energy. This tripartite arrangement was supported by Norton Rose Fulbright. [17]

The 15-year solar supply agreement with Maoneng is the first of its kind in Australia – bringing together a retailer, developer and corporate – and will allow UNSW to achieve its goal of carbon neutrality on energy use by 2020.

At the same time, there is significant interest in the potential of retail PPAs to incorporate some form of energy storage such as utility scale battery storage.

Kelly Davis, Senior Consultant of Norton Rose Fulbright commented: *"Most new renewable energy projects in development around Australia are "Storage Ready". This means that ESS is contemplated as part of the planning and environmental consents and necessary land rights. We have recently started to see more interest from offtakers in combining ESS with a traditional RE PPA.*

This is being driven by a number of factors including:

- *the reducing costs of ESS*
- *the policy signals supporting storage and reliability generally*
- *the performance of the Tesla "giant" battery in SA*
- *the continuing high price of power particularly during the shoulder and peak events.*

Developers are also progressing more hybrid projects (such as wind, solar and ESS) so they can sell a firmer product to the market. We are increasingly seeing utility scale battery storage featuring in RE PPAs in one way shape or form and we anticipate a shift towards combined capacity and energy models going forwards as hybrid generation and storage Renewable Energy projects become the "norm"."

2.3.6 Strengthening the NSW economy

Beneficiaries: NSW State Government, Business, Community

How: Energy independence, Creation of new industry and employment

NSW is centrally placed on the NEM with significant interconnections to the other participating states. It has the potential to derive significant economic benefit through becoming a net exporter of energy by installing further generation and storage.

Ecoult Energy Storage Solutions is a global business, with their headquaters in Sydney, NSW. Ecoult provides grid scale battery solutions, originally developed in NSW from Australian innovation. The company currently employs 53 full time professionals in NSW and uses local manufacturers to develop product and services which are for the Australian market and for exported to countries such as North America and India.

CEO of Ecoult, John Wood commented that large scale storage is an emerging industry, with big opportunity for growth to provide products and services. He added that Ecoult supplies large systems into overseas markets where market incentives exist, such as those where batteries make a real contribution and where ancillary services are valued. Ecoult has undertaken several projects in Australia to date, and sees that with the generation market changing, there will more economic cases for batteries to be installed at grid level in NSW.

2.4 Risks for implementation

As a technology, utility scale battery storage is still in its infancy. Historically, there has been little demand for utility scale battery storage functionality and capital costs have been prohibitively expensive. In recent years, significant changes to Australia's generation mix have created multiple technical and commercial drivers. Simultaneously, the cost of battery technologies has fallen drastically, driven in part by investment in mobile phones, consumer electronics and electric vehicles.

Despite the emergence of a number of commercial and technical drivers, there are many challenges that are slowing the commercialisation of utility scale battery storage projects in Australia. The Snowy Mountains Scheme 2.0 is one such threat.

In 2017, the Turnbull Government announced plans to increase generation from the Snowy Hydro scheme (which it jointly owns with the NSW and Victorian governments) by 50%, adding 2,000MW of renewable energy to the NEM. [18] The unprecedented expansion could produce 20 times more energy than the 129MWh from the South Australian Tesla battery and deliver it constantly for almost a week. [18]. At a cost of $3.8 - $4.5B, it is planned to deliver first power generation in 2024. The final investment decision is expected in late 2018.

Other barriers are categorised as technical, commercial and regulatory in nature, discussed below.

2.4.1 Technical risks

While the capability of utility scale battery storage technology has risen over time, it is clear that there is room for improvement in technical performance. In particular, degradation, design life (10-12 years), and availability (~95%) are considered areas where utility scale battery storage performance could improve. While improvement in these fields is not deemed essential for commercialisation of utility scale battery storage, it would certainly assist.

In addition, there is need for better understanding of utility scale battery storage technical characteristics. This includes the relationship between charging regime and degradation rates (which may influence the choice of utility scale battery storage applications), state of charge accuracy, warranties and their limitations, availability of test data, and the standardisation of technical specifications.

Grid connection is another area that presents technical risks. Incorporating utility scale battery storage into the grid is challenging for system planners due to potential to drive large swings in power flow over very short times. Also, given the inexperience in dealing with utility scale battery storage projects, there is the potential for the grid connection processes to be long and complicated, which can lead to project delays. This is largely because AEMO and NSPs need to familiarise themselves with the technology, its impact on power systems, and to determine appropriate connection requirements.

2.4.2 Commercial risks

The most significant challenges for utility scale battery storage project proponents relate to commercial and financial risks, outlined in Table 3. Most notably, there is considerable risk relating to forecast revenue for the utility scale battery storage market applications. While some level of risk is very normal for any infrastructure project exposed to a market price, battery storage revenue appears to be particularly challenging from a risk perspective. This is because the markets that utility scale battery storage projects rely on for revenue are particularly small, vulnerable to the impact of new technologies, and have limited appetite for contracting revenue, particularly for extended periods of time.

Seed Advisory Pty Ltd commented:

"Battery participation in Australian wholesale energy, frequency and network markets is at the beginning of a long journey. Batteries can register to participate in the wholesale electricity market, where AEMO requires batteries of 5 MW plus to schedule their operations, both charging and discharging, and will shortly be able to participate in frequency and ancillary markets run by AEMO…. Analyses that rely on "revenue stacking", that is, a battery achieving income from all of these sources need to consider the likelihood of a revenue source being available (network services) in the location the battery is located; the battery's ability to provide customers' requirements (financial contracts); the level of external competition; and the potential for its contracted services to conflict (high prices and high network stability requirements may coincide), in estimating a battery's likely revenues, as opposed to its theoretical maximum revenue."

For further details refer to Appendix D

Table 3: Overview of commercial risks

Commercial risks	
Revenue uncertainty	Revenue uncertainty in an inherent risk for utility scale battery storage projects with significant revenue risk found across each of the largest revenue sources (FCAS and wholesale arbitrage in particular). This risk can be diluted within a larger project (e.g. wind farm). variable renewable energy generators can use utility scale battery storage as a hedge against high FCAS causer pays costs Vertically integrated retailers with a generation portfolio can internalise this risk through a portfolio approach.
Value stack trade-off	As revenue streams are stacked, there is often a trade-off between different services. This trade-off is particularly strong when providing network services, where capacity may need to be reserved for back-up power applications. Currently it is unclear what degree of compromise between value streams is likely for a given project. Evaluating the materiality of this value stack trade-offs appear to be both highly complex and very project specific.
Saturation of FCAS markets	While utility scale battery storage is technically highly suited to providing FCAS services, FCAS markets are forecast to be quickly saturated as they are inherently shallow. Oversupply in this market could be caused by installation of excess utility scale battery storage capacity, or through other technologies (e.g. demand response, new interconnectors). This creates a barrier for first movers who see attractive FCAS market prices but are concerned about the longevity of the investment signal.
Financing challenges	Financiers require more experience on both the technology and revenue sides of utility scale battery storage projects. Currently, the higher complexity and uncertainty of utility scale battery storage projects inflates the due diligence costs to impractical levels. In addition, it is difficult to finance projects due to the high degree of revenue uncertainty. Innovation is required to firm-up utility scale battery storage project revenue such that financiers can be sufficiently confident of the integrity of their investment.

2.4.3 Regulatory risks

While there appear to be no 'hard' regulatory barriers restricting the operation of utility scale battery storage in the NEM, there are a number of regulatory challenges facing utility scale battery storage project proponents, outlined in Table 4. These challenges include uncertainty regarding:

- Interpretation of the National Electricity Rules
- Treatment of utility scale battery storage in normal process (e.g. grid connection, generator dispatch)
- Impact of the large amount of regulatory change currently proposed in the NEM.

Table 4: Overview of regulatory risks

Risk	Detail
Regulatory interpretation	
Regulated revenue (networks)	There is uncertainty regarding the interpretation of Ring-Fencing and Shared Asset Guidelines in the context of utility scale battery storage projects. Clarification of interpretation of these guidelines to utility scale battery storage projects is essential in understanding the potential role for networks to play in driving utility scale battery storage investment, as well as the potential to integrate network services into the value stack.
DuoS / TuoS charges	Utility scale battery storage may be required to pay network charges (DuoS/TuoS) for consumption of energy from the network. This would significantly impact the business case for energy shifting applications.
AEMO dispatch requirements	It is not clear how a battery would be required to operate between 5-minute dispatch instructions. While it seems logical that a straight line interpolation between dispatch instructions is reasonable, it is not clear what will be required by AEMO.
Charging behaviour	It is currently unclear what limitations might be placed on utility scale battery storage charging regimes. If a battery is held to day-in-advance charging and discharging bids, it will be unable to respond to changing market conditions. Similarly, if a battery has full flexibility to charge and discharge as desired this would facilitate opportunistic manipulation of market prices.
LGCs	There is concern that locating utility scale battery storage at a renewable generator may impact its ability to generate LGCs. This concern is due to uncertainty regarding the definition of auxiliary load on site, utility scale battery storage efficiency losses, and the impact of utility scale battery storage imports from the grid. However, this concern may become less relevant when the RET scheme is replaced by the NEG as currently predicted.
Changing regulatory environment	
Rule change: 5 minute settlements	Current market arrangements do not incentivise fast response technologies to enter the market. A battery dispatching into a high price dispatch period is paid at the 30-minute average spot price. Under certain bidding conditions, this may be insufficient in driving investment and operation of utility scale battery storage systems.
FFR markets	The AEMC has proposed that TNSPs take responsibility for ensuring that there is sufficient inertia and/or FFR in their network. This may create uncertainty in two different manners: 1. Potential new revenue stream for utility scale battery storage projects 2. Addition of more utility scale battery storage projects, leading to an oversupply of FCAS capability in the market
Generator connection standards	The Finkel Review has suggested that new requirements be introduced for all generators to have FFR capability. This may increase demand for utility scale battery storage at variable renewable energy generators. Furthermore, this additional utility scale battery storage capacity could lead to an oversupply of FCAS capability in the market, resulting in very low market prices.

In an overview to an AEMC Market Review in 2015, the AEMC defined the evolving areas for energy storage:

"Storage is particularly interesting for the AEMC because of its potential to touch the whole electricity sector:

Storage can allow consumers and businesses to respond to time of use tariffs and to reduce demand charges that reflect their impact on the network. Storage can aid self-supply if consumers have solar PV.

- *Storage can reduce congestion on both transmission and distribution lines and other network assets, potentially shaving the peak demand that drives a lot of network augmentation.*
- *Storage can provide ancillary services like frequency control, voltage support and potentially even system restart services.*
- *Storage assets can substitute for generation, help to integrate intermittent renewable generation and allow trading between times of higher and lower wholesale electricity prices.*

The AEMC report acknowledged that this challenges the regulatory model, which was been built around defined roles along the supply chain [19]*."*

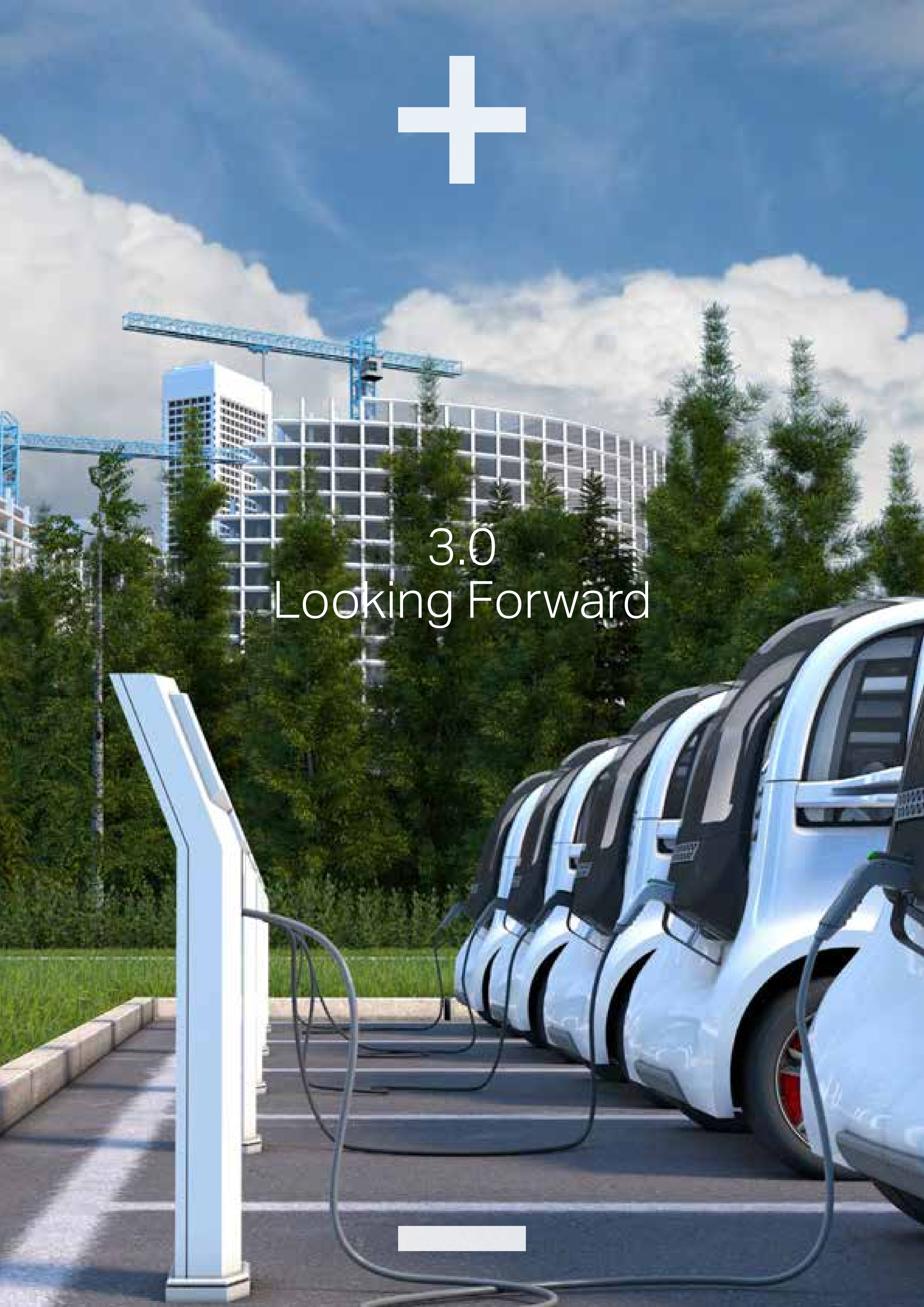
Subsequently, there have been several requests for comment from stakeholders on specific areas of interest.

Responses from the AEMC Frequency Control Frameworks Review Issues Paper included the following comments from Tesla Motors Australia:

"From a principles perspective, Tesla believes the following:

- *The current structure of the NEM was not set up to fully cater for the incorporation of non-synchronous technologies and battery energy storage.*
- *The current treatment of battery energy storage as both a generation asset and a customer load leads to redundancies, additional administrative burdens for battery operators, and reduces the potential of accessing the full technical capabilities of the battery energy storage system.*
- *Existing market and technical requirements make it difficult for brownfield retrofitting of battery energy storage to existing renewables.*
- *Battery energy storage, as a distributed energy resource, can provide substantial benefits to existing network infrastructure. The current network service provider (NSP) approach to connection approval should be considerate of the value and opportunities, as much as the need to mitigate potential risks."*

In the conclusion, Tesla's submission noted, "We look forward to seeing technical specifications adapt to emerging technologies; new markets introduced to recognise necessary services; and existing regulatory frameworks adjust to appreciate the services of new technologies." [20]



3.0 Looking Forward

The future role of batteries in the NEM will largely be determined by the extent and efficacy of efforts made to address the technical, commercial and regulatory risks discussed in Section 2.3.6. The rate of retirement of thermal generation capacity, will also largely impact the future penetration rate of utility scale battery storage.

Most NSW development approvals for solar or wind farms recently lodged include the potential for future installation of utility scale battery storage, in anticipation that these risks will be addressed.

A pilot undertaken at scale in NSW would provide knowledge sharing and lessons learnt, in a similar manner to the utility scale battery storage projects instigated and funded by the SA, QLD, and VIC State Governments and ARENA.

3.1 Technical trends

Social trends that result in increased peak energy demand provide the greatest opportunities for utility scale battery storage. These trends are likely to include the electrification of transport and other industries, digitalisation increasing the demand at data centres and decentralisation of utilities in a way that decreases coordination and control.

As Australia moves to electrification of transport, there may be niche opportunities for utility-scale battery storage, as this may challenge network operators. Energy management and storage might be one option for managing areas of high demand, as large numbers of vehicles seek to charge at peak times at the end of the day.

Electric Vehicle (EV) charging infrastructure development is in the early days in NSW, however being addressed by the NRMA, Australia's largest roadside assistance membership organisation covering NSW and the ACT.

The NRMA Social Dividend Investment Strategy includes developing a vehicle fast charger network and proposes to *"establish Australia's largest electric vehicle fast-charging network, suitable for a range of electric vehicles"*. [21]

3.1.1 Battery trends

An emerging trend is that of long duration utility scale battery storage; long-duration being used to refer to energy storage which is available for four hours or more. Several companies are now offering product developed around the flow battery technology to meet this criterion, and many of the manufacturers of flow battery storage systems also claim that they provide longer lifespans than lithium-based utility scale battery storage.

With further development of these and other innovative technologies, together with more implementation, the choice of the type of utility-scale battery storage is widened, leading to lower costs across all battery types.

Lachlan Blackhall of ANU commented that

"Although many of the existing and planned utility scale battery systems are based on lithium chemistries, there are battery systems based on other chemistries that offer alternate energy storage and power delivery characteristics. Utility scale battery systems based on vanadium and other flow chemistries are likely to increase in adoption, particularly as prices drop due to increasing global demand for these systems which has been highlighted by recent installations in China [22]."

3.2 Commercial trends

Developers have interest in utility scale battery storage in NSW; however, this is still early days and lower cost of batteries would be one element to make the economic proposition more viable.

Utility scale battery storage costs remain high compared to most other technologies but have decreased in recent years. The declining cost path is expected to continue, the drivers being increased deployment and renewed interest in storage. Lithium-ion chemistry batteries have seen the most dramatic cost reduction as the technology has been deployed in the power sector and the growing EV market [23]. Drivers of cost reduction include economies of scale due to improvements in manufacturing facilities and output, evolution of balance of system and software platforms, learning and development of in-country installation practices [24].

3.2.1 Funding Opportunities

With strong interest in further projects, some State Governments and ARENA have provided funding for pilot projects. In South Australia, the state government has contracted 70MW and 39MWh for network support services from the Hornsdale Power Reserve 100MW, 130MWh utility scale battery storage system. ARENA and the Victorian State Government have jointly provided $50 million of funding to deliver 55MW of power, with 80MWh of storage, through the rollout of two utility scale battery storage projects in Victoria. Under the Powering Queensland Plan, the Queensland state Government is conducting a reverse auction for up to 100MW of energy storage, which is likely to include utility-scale battery storage.

The very recent announcement in May 2018 by ARENA [25] of $7 million funding initiative will support trials to determine how solar parks, wind farms or enabling technologies such as batteries can provide grid stability and security services. Submissions for this funding are expected to come from a variety of geographic locations across Australia.

3.3 Regulatory trends

There are currently many initiatives underway in the market that are highly relevant to the role of utility scale battery storage. These include the Finkel Review (refer to section 1.2), AEMC's System Security Market Frameworks Review and AEMO's Future Power Systems Security Program (which together considered the fast frequency response and inertia ancillary services proposals discussed in 3.3.1 and 3.3.2 respectively) and state-based funding and auction programs (refer to 3.2.1).

The results of these programs are likely to have a large impact on the role of utility scale battery storage and its financial drivers. Some of the proposed changes are likely to drive investment in utility scale battery storage, or even assist the business case. However, until these changes are implemented, the possibility of regulatory change brings uncertainty to the business case.

3.3.1 Fast Frequency Response

The AEMC's proposal for TNSPs to procure FFR should help drive utility scale battery storage projects, which are highly suited to providing this service. However, projects currently in development cannot rely on revenue from this service when they assess their financial model. The impact of the rule change on revenue projections is more likely to be negative due to possible market saturation. In particular, utility scale battery storage projects contracted to provide FFR will likely saturate the FCAS markets, leading to a significant revenue risk for projects currently in planning.

"The AEMC is conducting a review to address deteriorating frequency performance in the national electricity market. With more wind and solar now in the system, and coal-fired generators exiting, the technical characteristics of the electricity grid are changing. This makes it more challenging to maintain a stable frequency and keep the system secure."

This provides opportunities for large scale batteries as one of the options to potentially become valued in this changing market. A Frequency Control Frameworks review is currently on-going and attracting a number of submissions [26], including those from Tesla and Fluence.

It is expected that this discussion will lead to a developing a more open market in the NEM for services provided by battery storage.

3.3.2 Inertia ancillary services

A recent AEMC rule change request proposing the establishment of an inertia ancillary services market, which may have provided clarity around the deployment of 'synthetic' inertia like batteries, was turned down following further consideration and stakeholder feedback. The AEMC has since made a final rule determination (commencing July 2018) placing the obligation on Transmission Network Service Providers (TNSPs) to make available the minimum level of inertia needed to ensure power system security, which impacts the role of utility scale battery storage in the market.

3.3.3 5 minute rule

Currently, in the spot market in the NEM, the settlement period is 30 minutes. However, the Australian Energy Market Operator (AEMO) dispatches electricity every five minutes and generators must bid in five-minute blocks. Therefore, the spot price for a 30-minute trading interval is the average of six dispatch interval prices. All generators dispatched in that trading interval receive the spot price. This will change in 2021, for further details refer to Appendix C.

3.3.4 Federal policy under review

The development of the National Energy Guarantee is on-going and expected to reach final implementation later in 2018, subject to the various inputs of stakeholders. Many industry members have provided submissions for this important policy change [27].

The Energy Security Board's High Level Design Document states:

"Over the past fifteen years the energy sector has undergone a significant transformation. New and evolving technologies are changing the way we consume and produce electricity. This transformation of the sector continues with many technologies currently maturing and competing with traditional technologies while new and emerging technologies (for example, batteries) look likely to further revolutionise the sector. While undergoing this transition has had many positive benefits, it has also left our energy system vulnerable to escalating prices while being both less reliable and secure.

The National Energy Guarantee (Guarantee) provides the opportunity to resolve fifteen years of energy and climate policy instability. It is designed to integrate energy and emissions policy in a way that will encourage new investment in clean and low emissions technologies while allowing the electricity system to continue to operate reliably. The Guarantee will provide a clear investment signal, so the cleanest, cheapest and most reliable generation (or demand response) gets built in the right place at the right time [28]"

3.3.5 Integrated System Plan

In its role as NEM National Transmission Planner, AEMO is preparing an inaugural Integrated System Plan (ISP) for the NEM, which considers how the energy industry transformation affects the need for infrastructure development and how the essential technical requirements of the power grid will continue to be efficiently met [29].

The NSW Government's submission on the ISP notes:

"While NSW benefits from good quality energy resources located close to the existing transmission and distribution networks, many of the areas with the strongest resource potential are located remote from the existing network. Transmission extensions to new Energy Zones would help unlock new areas of NSW for energy development, which may be needed to offset the closure of existing traditional energy generators over coming decades. As the state with the largest energy load in the NEM, locating Energy Zones in NSW would also lead to efficiencies by minimising energy lost during transmission between regions, capitalising on NSW's central location. Importantly, the identification of Energy Zones in NSW would give the private sector greater certainty to make efficient long-term investment decisions and would support recommendations from both the Independent Review into the Future Security of the National Electricity Market (Finkel Review) and NSW Energy Security Taskforce. The Finkel Review recognised that Energy Zones offer a means of efficiently developing and connecting new large-scale generation capacity, and similar models have been successfully implemented in other jurisdictions around the world [30]."

3.4 Preparing for the future grid in NSW

The NSW Government has undertaken a number of initiatives and programs in order to support the conditions for private investment in energy technologies, prior to the submission to the ISP. These initiatives focus on promoting and facilitating renewable energy companies and projects into Sydney and NSW as well as positioning NSW as a renewable energy industry hub in Australia.

These local initiatives have provided opportunities for the growth of renewable energy generation, and will continue to prepare the grid for the uptake of utility scale battery storage.

Transmission infrastructure strategy

NSW Government is preparing a new transmission infrastructure strategy to help the state access the low-cost renewable generation. The strategy will integrate high resource areas and transmission planning to ensure that infrastructure is developed where it will provide the greatest benefit, unlocking Energy Zones [31]

Pumped hydro developments

The ability to store energy for later use is critical to embedding renewable energy generation into a reliable electricity system. Pumped hydro is a seasonal (longer duration) storage that complements battery storage systems.

WaterNSW, the state's bulk water supplier and river operator, is investigating the opportunity for private developers to make energy investments in the organisation's existing infrastructure and water resources.

The Government sees the potential for sensible infrastructure developments on WaterNSW assets, to support a more secure, affordable and reliable energy mix [32]

NSW Demand Response Initiative

The NSW Government and ARENA have jointly funded a $14 million Demand Response Program to help maintain NSW energy security when it's most under pressure, such as during extreme heat wave events.

Users will be incentivised to reduce their energy usage, upon request from AEMO, to help restore the balance between supply and demand, taking pressure off the energy system when it's most needed. [33]

NSW Energy Security Taskforce

The NSW Energy Security Taskforce released its Final Report on 19 December 2017, which examines issues that need to be addressed to strengthen the longer-term resilience of the NSW electricity system. The report considers the challenges of achieving a stable and reliable power system, which is characterised by low electricity costs and low emissions, while managing the transition to new forms of generation technologies in a changing environment. [34]

NSW Renewable Energy Action Plan

The NSW Renewable Energy Action Plan aims to attract renewable energy investment, build community support and attract and grow renewable energy expertise. The NSW Government is focused on practical steps to remove barriers to investment in renewable energy.

"With the largest installed renewable energy capacity in Australia, and with abundant renewable energy resources, NSW is well positioned to attract future renewable energy development." [35]

This document is a snapshot of the current market situation as understood at May 2018 and is expected to have revisions in the future. Please contact the Australian Energy Storage Alliance at info@energystoragealliance.com.au to obtain a copy of any later released version.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Appendix A

Planned Variable Renewable Energy Generation

Table 5: Table 5 Planned wind and solar in NSW [9]

Plant	Size (MW)	Type	Location
Under Construction			
Crookwell 2 Wind Farm	91	Wind	Crookwell
Glen Innes Wind Farm	75	Wind	Glen Innes
Sapphire Wind Farm	435	Wind	Sapphire
Silverton Wind Farm	300	Wind	Silverton
Coleambally Solar Farm	150	Solar	Coleambally
Dubbo Solar Farm	24.2	Solar	South Keswick
Manildra Solar Farm	42.5	Solar	Manildra
Narromine Solar Farm	29	Solar	Narromine
White Rock Solar Farm	20	Solar	Glen Innes
Planned			
Bango Wind Farm	200	Wind	Rye Park
Biala Wind Farm	100	Wind	Biala
Birrema Wind Farm	264	Wind	Bookham
Bodangora Wind Farm	100	Wind	Bodangora
Capital 2 Wind Farm	100	Wind	Tarago
Collector Wind Farm	160	Wind	Cullerin
Coppabella (Yass Valley) Wind Farm	295	Wind	Bowning
Crookwell 3 Wind Farm	102	Wind	Roslyn
Crudine Ridge Wind Farm	136	Wind	Pyramul
Granite Hills Wind Farm	132	Wind	Steeple Flat
Kyoto Energy Park Stage 4	30	Wind	Scone
Liverpool Range Wind Farm	1008	Wind	Cassilis
Paling Yards Wind Farm	204	Wind	Taralga
Rugby Wind Farm	170	Wind	Rugby
Rye Park Wind Farm	340	Wind	Rye Park
Uungula Wind Farm	622	Wind	Yarrabin
White Rock Stage 2	202	Wind	Glen Innes
Avonlie Solar Farm	200	Solar	Sandigo
Beryl Solar Farm	87	Solar	Gulgong
Bogan River Solar Farm	12	Solar	Nyngan
Bomen Solar Farm	120	Solar	Bomen
Brewongle Solar Farm	146	Solar	Brewongle
Brocklehurst Solar Farm	29	Solar	Brocklehurst
Capital Solar Farm	50	Solar	Bungendore
Carrick Solar Farm	138	Solar	Carrick

Plant	Size (MW)	Type	Location
Culcairn Solar Farm	150	Solar	Culcairn
Currawarra Solar Farm	195	Solar	Maryung
Darlington Point Solar Farm	275	Solar	Darlington Point
Dunedoo Solar Farm	66	Solar	Dunedoo
Finley Solar Farm	170	Solar	Finley
Gidginbung Solar Farm	15	Solar	Gidginbung
Gilgandra Solar Farm	40	Solar	Eumungerie
Goonumbla Solar Farm	70	Solar	Parkes
Gunnedah Solar Farm (Ironbark)	27	Solar	Gunnedah
Gunnedah Solar Farm (Photon)	165	Solar	Gunnedah
Gunning Solar Farm	316	Solar	Gunning
Hay Sun Farm	100	Solar	Hay
Hillston Sun Farm	85	Solar	Hilston
Jemalong Hybrid Solar Park	50	Solar	Jemalong
Kyoto Energy Park Stage 3	10	Solar	Scone
Leeton Solar Farm	29	Solar	Leeton
Limondale Sun Farm	250	Solar	Balranald
Maryvale Solar Farm	196	Solar	Maryvale
Metz Solar Farm	100	Solar	Hillgrove
Molong Solar Farm	25	Solar	Molong
Mumbil Solar Farm	178	Solar	Mumbil
Narrabri South Solar Farm	60	Solar	Narrabri

Plant	Size (MW)	Type	Location
New England Solar Farm	800	Solar	Uralla
Nevertire Solar Farm	105	Solar	Nevertire
Orange Grove Sun Farm	110	Solar	Orange Grove
Riverina Solar Farm	30	Solar	Yoogall
Sandigo Solar Farm	300	Solar	Sandigo
Sapphire Solar Farm	200	Solar	Sapphire
Springdale Solar Farm	120	Solar	Sutton
Sundown Solar Farm	600	Solar	Newstead
Sunraysia (Balranald) Solar Farm	200	Solar	Balranald
Suntop Solar Farm	286	Solar	Suntop
Tamworth Solar Farm	80	Solar	Somerton
Tarleigh Park Solar Farm	90	Solar	Blighty
Vales Point Solar Project	45	Solar	Mannering Park
Wagga Wagga (Gregadoo) Solar Farm	47	Solar	Gregadoo
Walgett Solar Farm	29	Solar	Walgett
Wee Waa Sun Farm	55	Solar	Wee Waa
Wellington North Solar Plant	300	Solar	Bodangora
Wellington Solar Farm	160	Solar	Wellington
Wollar Solar Farm	400	Solar	Tichular
Yarrabee Solar Park	900	Solar	Morundah

Appendix B

Regulatory Parameters

The interim arrangements to inform review of the NER framework applying to energy storage cover six broad areas, key considerations for which include:

1. **Registration:** AEMO' s policy is that proponents of battery systems with an aggregate nameplate rating greater than or equal to 5 MW, whether directly connected to the network or integrated behind the meter with new or existing generation, are to be registered as both Generators and Market Customers.
    - Their generating units are to be classified as Scheduled and Market and the load classified as Scheduled load. [36]
2. **Metering:** Parties must register a metering installation with AEMO prior to being able to operate in the NEM.
    - Batteries may be connected through one or more connection points to the network, and a NER-compliant metering installation is required for each connection point.
    - For single connection points for battery charge and discharge there a single Financially Responsible Market Participant (FRMP) registered for that connection point is required.
    - However, consideration should be given as to the need for individual meters for each of battery charge and discharge operating function, should the battery be both charging and discharging in any one 5 minute dispatch period (for example, for the provision of contingency Frequency Control Ancillary Services (FCAS), which is discussed in Section 2.1). [36]
    - Multiple connection point arrangements are likely to require additional switching and metering infrastructure.
3. **SCADA and data collection:** Batteries requiring registration will be required to provide AEMO with the following data via SCADA:
    - Current state of charge (MW)
    - Current charge rate (MW)
    - Current discharge rate (MW)
    - Any other data required under their generator performance standard
    - Any other data required by the Market Ancillary Services Specification (MASS) if operating in FCAS markets.

This is needed so as to help AEMO accurately forecast and dispatch the necessary energy and system services required to maintain a secure and reliable power system, given batteries have the ability to shift the time at which energy produced from renewable energy sources is consumed. It will allow AEMO's systems for forecasting generation of wind energy, solar energy and underlying demand to take in a level of real-time information on how battery systems are interacting with other generation assets. [36]

4. **Performance standards:** Batteries requiring registration will be required to submit a set of Generator Performance Standards to the relevant Network Service Provider (NSP).
    - These will detail the level of technical performance required for on-going operation of the battery system (as both a scheduled generator and scheduled load).
    - If installed as part of an existing generating system or customer connection, and there are changes to the existing plant and/or performance of the existing plant, there will be requirement for AEMO and the relevant NSP to approve settings/configuration changes and revised performance standards. [36]

5. **TUOS and DUOS:** Intending battery connection applicants will need to negotiate 'use of system charges' with the relevant TNSP/DNSP.
   - Under the NER, it is the responsibility of NSPs to negotiate in good faith with applicants.
   - Each NSP determines the charges according to its own pricing methodology.
6. **Participation in ancillary services markets:** Parties looking to participate in FCAS markets must comply with the requirements of the MASS and register as ancillary service generating units.
   - AEMO may undertake trials to test the performance of new technologies with registered ancillary service generating units (in future versions of the MASS).
   - AEMO may also introduce scope requiring demonstration of the ability of different technologies to provide FFR services, as a part of the AEMC's rule change process on Inertia Ancillary Services Markets, which is currently under development. [36]

Appendix C
5 Minute Rule Change

Rule Change: Five Minute Settlement Rule

Current Rule and Process to Change

Currently, in the spot market in the NEM, the settlement period is 30 minutes. However, the Australian Energy Market Operator (AEMO) dispatches electricity every five minutes and generators must bid in five minute blocks. Therefore, the spot price for a 30 minute trading interval is the average of six dispatch interval prices. All generators dispatched in that trading interval receive the spot price.

On 4 December 2015, an initial rule change request was submitted by Sun Metals, a zinc refinery and large energy user, that proposed to align dispatch and settlement in the NEM through a modification of the settlement interval to five minutes. Following numerous stakeholder consultations and a public forum, the AEMC made its decision to change the settlement period for the electricity spot price from 30 minutes to five minutes.

Changes to the Rule and Time-Frame

The AEMC published its final rule determination and final rule on 28 November 2017. The final rule redefines the current definition of "trading interval" under the National Electricity Rules minute timeframe for settlement from a 30 minute to a five minute period.

The rule change will come into effect from Thursday, 1 July 2021. As of this date, bidding and offering into the NEM, calculation of trading amounts, settlement, dispatch, periodic energy metering and other processes must be carried out on a five minute basis. In practical terms, types 1, 2, 3 and certain type 4 meters will now have to record and provide five minute data, which will necessitate changes to metering infrastructure and contractual arrangements.

There are various transitional provisions set out in the final rule (contained in Schedule 7), which commenced on 19 December 2017. The AEMO is currently working with the industry to develop an implementation plan, with policy guidance from the AEMC. The Australian Energy Regulator will also monitor the conduct of market participants throughout the transition period.

Potential Impact of Battery Companies: How Bidding Might Change for Short Duration Storage

In general, battery companies welcome this rule change on the basis that five minute settlement provides a better price signal for investment in fast response technologies.

For example, Darius Salgo of Nexergy noted that the reform will "lead to more effective compensation for fast response generation and participants capable of providing fast response ancillary services." This is because, as Robert Stevenson of Ecoult pointed out, in other jurisdictions " there is now a body of evidence to show conclusively that these technologies can perform economically and well in the types of applications that will appear under short-duration settlement conditions, for instance allowing PV and wind generators to confidently bid into five minute periods and buffering existing gas generation that cannot ramp quickly enough to do so."

Ultimately, the rule change is expected to benefit individual consumers and the market as a whole because, as Mike Swanston on behalf of the Customer Advocate noted, five minute settlement will encourage "technologies that respond to fast load change, with flow-on benefits for energy balancing, network optimisation and the optimum adoption of low-carbon generation."

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Appendix D

Value Stacking

Value Stacking

Battery participation in Australian wholesale energy, frequency and network markets is at the beginning of a long journey. Batteries can register to participate in the wholesale electricity market, where AEMO requires batteries of 5 MW plus to schedule their operations, both charging and discharging, and will shortly be able to participate in frequency and ancillary markets run by AEMO. In both cases, prices are set competitively; the battery's operator will receive the relevant market price for its output (the Regional Reference Price or spot price in the wholesale market, and the clearing price in the frequency markets); and, in the frequency markets, the volume of services required is set by the market operator. Although the 2017/18 Demand Response trial by AEMO and ARENA is finished, batteries will be able to participate in future demand response programs, provided that the battery meets AEMO's requirements for communications and passes the required performance tests.

Standalone battery participation in the hedge or financial markets is more difficult. Typical hedge contracts are denominated in multiples of 1 MW, and cover peak, off-peak or total contract hours during a given month, quarter or year: batteries with a capacity of less than 1 MW and/or unable to provide energy over a period of up to 16 hours in the case of a peak swap covering the hours 7am to 11pm are unlikely to be able to offer financial contracts other than as part of a wider portfolio of generation.

Network stability and support services are typically sourced competitively, are specific to a given network location or area, subject to regulatory oversight, and are infrequent, particularly in networks which have had large recent investment programs. These programs, where available compete with other providers and networks' own alternative solutions: networks' willingness to enter into contracts for support services is capped by the cost of the alternative network investment.

Analyses that rely on "revenue stacking", that is, a battery achieving income from all of these sources need to consider the likelihood of a revenue source being available (network services) in the location the battery is located; the battery's ability to provide customers' requirements (financial contracts); the level of external competition; and the potential for its contracted services to conflict (high prices and high network stability requirements may coincide), in estimating a battery's likely revenues, as opposed to its theoretical maximum revenue.

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