Large-Scale Battery Storage Knowledge Sharing Report

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Report prepared by
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ARENA

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Glossary

Term	Definition
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control
ARENA	Australian Renewable Energy Agency
BESS	Ballarat Energy Storage System
BoL	Beginning of Life
C&I	Commercial and Industrial
Capex	Capital Expenditure
CPF	Causer Pays Factor
DNSP	Distribution Network Service Provider
EoL	End of Life
EPC	Engineering, Procurement and Construction
ESCOSA	Essential Services Commission of South Australia
ESCRI	Energy Storage for Commercial Renewable Integration
ESS	Energy Storage System
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
FIA	Final Impact Assessment
GESS	Gannawarra Energy Storage System
GPS	Generator Performance Standards
HPR	Hornsdale Power Reserve
HV	High Voltage
LSBS	Large-Scale Battery Storage
MASS	Market Ancillary Services Specification
MCR	Maximum Continuous Rating
NEM	National Electricity Market
NER	National Electricity Rules
NLAS	Network Loading Ancillary Service
NSCAS	Network Support and Control Ancillary Service
NSP	Network Service Provider
O&M	Operations and Maintenance
Opex	Operational Expenditure
OTR	Office of the Technical Regulator
PPA	Power Purchase Agreement
PSCAD	Power Systems Computer Aided Design
RoCoF	Rate of Change of Frequency
SCR	Short Circuit Ratio
SIPS	System Integrity Protection Scheme
SOC	State of Charge
SRAS	System Restart Ancillary Services
TNSP	Transmission Network Service Provider
UFLS	Under Frequency Load Shedding
VCAS	Voltage Control Ancillary Services
VRE	Variable Renewable Energy

1. EXECUTIVE SUMMARY

The electricity market is in the midst of a transition. Increasing shares of variable renewable energy generation have elevated the important role energy storage will play to support power system reliability and security. However, to enable new services and ensure the security of the power network, the market will need to adapt.

Large-Scale Battery Storage (LSBS) is an emerging industry in Australia with a range of challenges and opportunities to understand, explore, and resolve. To meet the challenges, it is important that learning opportunities are drawn from each project undertaken to increase the chances of success for future projects, bolster business cases, and realise the full potential of LSBS.

There are a number of technical, commercial, and regulatory opportunities that the market has already identified and is beginning to explore.

Key areas identified for further technical development are:

- **simulated/synthetic inertia** – typically available as a function from voltage source inverters (i.e. those with grid forming capability), with other innovations also emerging involving a comparable operating mode in parallel with current source inverter control
- **system strength** – improved knowledge of capability of different battery inverters to provide system strength support
- **power system modelling** – modelled demonstration of the capability of high performance battery inverters to support increasing Variable Renewable Energy (VRE) penetration and/or further technical developments or performance specifications required to facilitate the transition
- **bidding algorithms** – development of customisable and potentially supplier agnostic bidding tools to maximise revenue streams and the commercial returns for battery projects in a complex energy market
- **flexible warranties** – further development of battery degradation warranty structures that provide flexibility to battery operators while also managing supplier risk
- **degradation management** – further development of strategies and contracting structures to extend project life
- **decentralisation and islanding** – further development of how battery storage can support increasing levels of islanding and embedded microgrids at various scales of islanded network.

Commercial viability of battery projects requires further development of market structures and incentive mechanisms to recognise and value the services LSBS can provide, including for Fast Frequency Response (FFR) and simulated inertia.

Proponents also continue to develop innovative solutions to extract value from the potential for LSBS to operate within the existing market structure, including for curtailment management and minimising Causer Pays costs.

Regulatory reform in a number of areas, such as a new registration category for bi-directional resource providers (including energy storage) is on-going, to develop future-ready market structures and rules that are technology agnostic and will facilitate the procurement of the range of services that will be required to ensure a secure power system through the transition to higher VRE penetration.

This report summarises the key lessons and innovation opportunities for LSBS projects in Australia based on specific project insights gathered through the Australian Renewable Energy Agency (ARENA), Aurecon's industry experience, and publicly available information.

The LSBS projects analysed in this report were co-funded by ARENA, the South Australian Government and/or the Victorian Government, as well as the proponents themselves. ARENA acknowledges the important roles all parties played in delivering these projects.

2. INTRODUCTION

2.1 Background

The electricity market in Australia is in the midst of a transition. To support this energy transition, changes will be required to enable new services and ensure the reliability and security of the power network.

A study by the Smart Energy Council[1] released in September 2018 identified 55 large-scale energy storage projects of which ~4800 MW planned, ~4000 MW proposed, ~3300 MW already existing or are under construction in Australia. These projects include a range of storage technologies including LSBS, pumped hydro, and solar thermal. Excluding pumped hydro, these projects are estimated to provide over 4 GWh of grid-connected and off-grid storage.

LSBS systems have the potential to play a key role in maintaining power system reliability and security, however, the sector is still in early development in Australia. Going forward, this will require a shift in the market.

LSBS is an emerging industry in Australia, and it is important that maximum learning opportunities are drawn from each project undertaken to increase the learning rate for future projects, bolster business cases, and enable the full potential of LSBS to be realised.

This report summarises the key learnings and innovation opportunities for LSBS projects in Australia based on specific project insights gathered through ARENA which co-funded four projects under its investment priority "Delivering secure and reliable electricity", Aurecon's industry experience, and publicly available information.

2.2 Scope

The data and insights presented in this report are sourced, in a large part, from ARENA co-funded LSBS projects; Energy Storage for Commercial Renewable Integration – South Australia (ESCRI-SA), Gannawarra Energy Storage System (GESS), Ballarat Energy Storage System (BESS) and Lake Bonney Energy Storage System (Lake Bonney). In addition, Aurecon has been able to provide significant industry experience from their work with the Hornsdale Power Reserve (HPR), to broaden the knowledge sharing base of this report.

At the time of writing, only a handful of LSBS[2] projects are fully operational in Australia and only one has been operational for greater than 12 months, hence this report focuses primarily on the development and delivery of LSBS projects. All ARENA-funded projects have knowledge sharing obligations, and so it is anticipated that lessons from the Operations and Maintenance (O&M) phase of the projects will become available in due course.

1 Smart Energy Council (September 2018) "Australian Energy Storage Market Analysis"

2 For the purposes of this report, LSBS is defined as a battery >5 MW (to align with AEMO's generating system registration categories)

3. DATA COLLECTION

3.1 General

In order to achieve a thorough review of the current state of LSBS projects, three data sources were identified. These are outlined in the following sections and have allowed more detailed and in-depth knowledge to be gathered through the process.

3.2 Desktop research

To establish the extent of information available currently, a thorough desktop search was conducted. Data sources included publicly available project reports, industry literature, and additional information provided by ARENA. This allowed Aurecon to establish areas of further interrogation for subsequent information gathering activities.

The information gathering task highlighted the disparity in the level of information available on each project. ARENA's Knowledge Sharing role requires all projects to develop reports and information to share with the public. However, the differing stages of development of each project, together with the progression of their Knowledge Sharing Plans, explains this reporting effort. For example, the ESCRI-SA project has established an extensive public knowledge sharing portal while other projects have currently a limited overview information via the ARENA and other stakeholder websites. Section 7 contains a full list of data sources and references.

3.3 Knowledge sharing workshop

3.3.1 General

A LSBS Knowledge Sharing Workshop was hosted by ARENA on 21 May 2019, as an information sharing forum. The event had a clear purpose, as outlined below:

- share understanding between stakeholders on large-scale battery-related initiatives underway or under development
- share practical lessons and experiences from large-scale battery projects between industry stakeholders
- discuss solutions to technical, regulatory and planning challenges observed by battery projects throughout the industry
- consider the future system capabilities required from LSBS in a high renewable electricity grid
- identify areas requiring further demonstration and study.

Two members of the Aurecon project team attended the Workshop in order to comprehensively capture the information shared, for further analysis. The presentation slides were also made available to all attendees following the Workshop.

3.3.2 Topics

The topics covered at the Workshop addressed three key areas, items of which were presented by a range of stakeholders:

- state government large-scale battery initiatives
- lessons from the field
- future system capabilities.

In addition, there was a solution design activity held at the close of the day. This activity has not been included in the analysis for this report, although conversations triggered by the activity have been used to form insights in conjunction with other information.

3.4 Electronic survey

Building on the first two data collection activities, an electronic survey was developed in order to verify initial insights and uncover further details and new topics. The full set of survey questions can be found in Appendix A. Several stakeholder organisations were identified across the four projects, and each organisation received a sub-set of the full question set, based on their involvement in the projects.

3.4.1 Topics

While numerous questions were developed, the following topics represent the breadth of the survey questions.

- risks
- key functions/services
- innovations
- market participation
- CapEx and OpEx
- business case
- contracting structure
- grid connection
- O&M
- regulatory reform
- future opportunities

3.4.2 Respondents

All four ARENA-funded projects supplied some form of information in response to the survey. While some projects provided detailed and comprehensive answers, other projects only provided already publicly available information, which did not necessarily address the full set of questions posed by the electronic survey. This additional information was used in conjunction with other data sets to develop new insights and verify previous analysis.

4. PROJECT SPECIFIC INSIGHTS

4.1 General

The early stage of deployment of LSBS technology in Australia and range of innovations provides unique lessons for the market. While many of the insights gathered through the report are applicable to all LSBS projects, there are several key items which relate to a unique characteristic of a specific project. To demonstrate the diversity of the LSBS project space, each of the ARENA-funded projects is outlined below, with their key functions, innovations and applicable challenges.

Table 1: Summary of ARENA-funded LSBS projects

Project	Capacity	Storage	Key features	Status	Total project cost
ESCRI-SA	30 MW	8 MWh	Stand-alone – grid connected but during outage will operate with the 90 MW Wattle Point Wind Farm and rooftop solar PV Samsung – Li ion battery ABB – Inverter	Commissioned 7 September 2018	$30m Project page
Gannawarra Energy Storage System	25 MW	50 MWh	Co-located with 50 MW solar farm, using existing point of connection Tesla – Li ion battery and inverter	Commissioned 1 March 2019	$41.19m[3] Project page
Ballarat Energy Storage System	30 MW	30 MWh	Stand alone, located at substation LG Chem – Li ion battery Power Electronics – Inverter	Commissioned 30 November 2018	$19.93m[3] Project page
Lake Bonney	25 MW	52 MWh	Co-located with 279 MW Lake Bonney Wind Farm Tesla – Li ion battery and inverter	Construction complete – connection approval pending	$41.6m[4] Project page

ARENA committed $25 million to the Gannawarra and Ballarat projects, matching the $25 million committed by the Victorian Government under its Energy Storage Initiative.

The Lake Bonney project was co-funded by the South Australian Government and ARENA.

3 Co-funded with the Victorian Government
4 Co-funded with the South Australian Government

4.2 ESCRI-SA

4.2.1 General

The ESCRI-SA project is a 30 MW/8 MWh (12.2 MWh BOL) battery in Dalrymple, Yorke Peninsula, South Australia. The project is owned, and was developed, by ElectraNet and is operated by AGL. The full name of the project is Energy Storage for Commercial Renewable Integration – South Australia (ESCRI-SA).

Image: ElectraNet

4.2.2 Key services

The project's key functions are to provide Fast Frequency Response (FFR) to reduce constraints on the Heywood interconnector, generate revenue through energy arbitrage and contingency FCAS, provide an islanding service for the local network in conjunction with the Wattle Point Wind Farm, and to participate in the System Integrity Protection Scheme (SIPS).

4.2.3 Operational status

ESCRI-SA was commissioned in September 2019 and entered commercial operation in December 2018. This project was the first Australian Government funded LSBS project and created the precedent for the projects that followed. It is operating well technically to date, showing ability to provide all the intended services. The battery operator has provided feedback that the LSBS system is struggling to capture much arbitrage value due to the limited energy storage capacity of the system.

4.2.4 Innovations

The ESCRI-SA project demonstrates that a utility-scale battery can provide both regulated and competitive energy market services; it is also the first grid-connected battery owned by a Network Service Provider (NSP).

The project is also able to provide seamless transition to islanded operation in conjunction with the Wattle Point Wind Farm and rooftop PV. This has not been achieved before by a grid-connected battery in Australia and supports the case for LSBS providing security in networks with high penetrations of variable renewable energy. In the short term this is expected to be of particular significance in support of improved reliability for fringe of grid applications and in the long term may provide a pathway to high renewable energy fraction grids, including stand-alone power systems for isolated networks.

The ESCRI-SA project is also the first LSBS project in Australia to operate in voltage source mode as a virtual synchronous generator while grid connected (this capability is sometimes known as grid-forming). Benefits provided through this operating mode as compared to traditional current source inverters are:

- simulated inertia and improved voltage stability through the very fast response capability of voltage source inverters (although emerging developments are enabling these functions to also be provided through a parallel operating mode in some more advanced current source inverters)
- system strength through provision of fault current. While some current source inverters are also able to provide a fault current contribution, this is not recognised by AEMO as contributing to system strength since current source inverters can become unstable during disturbance events involving significant distortions in the voltage waveform. Voltage source inverters, such as those installed for the ESCRI-SA project, do not suffer such instabilities during disturbance events, which can enable their fault current contribution to be recognised as contributing to system strength.

4.2.5 Project-specific challenges

The integration of the Wattle Point Wind Farm in islanded operation was identified early on as a major risk for the project and provided some issues during commissioning but the system was ultimately successfully integrated. Other challenges included technical integration for seamless islanding and obtaining and refining models for evaluation of the GPS. In addition, the transition from grid-connected to islanded operation presented an issue at commissioning.

4.3 Gannawarra Energy Storage System

4.3.1 General

The Gannawarra Energy Storage System (GESS) is a 25 MW/50 MWh battery in Gannawarra, Victoria. The project was developed by Edify Energy and funded by Edify Energy and Wirsol Energy. The batteries were supplied by Tesla and the EPC contractor was RCR Tomlinson. The battery is now operated by Energy Australia.

4.3.2 Key services

The GESS has three primary functions; energy arbitrage (in co-ordination with the retrofit to the Gannawarra Solar Farm), load for the local network during network outage events, and regulation FCAS (contingency FCAS not yet registered).

4.3.3 Operational status

The GESS was commissioned on 1 March 2019. In the future, the battery is expected to be capable of monetising additional services including Fast Frequency Response (FFR), synthetic inertia and a range of other requirements that the grid might need.

4.3.4 Innovations

The GESS is the first integrated renewable generation and battery system in Victoria, and among the first in Australia. It is also the first retrofit LSBS project to an existing or under-construction solar farm which is connected behind the existing point of connection for the solar farm.

4.3.5 Project-specific challenges

The retrofit of the battery to the solar farm raised a number of issues, not addressed before in Australia including:

- in order to provide regulation FCAS, a direct Automatic Generation Control (AGC) connection to AEMO is required, which is not typically available at distribution network substations. Since the project is a DNSP connected asset this introduced additional complexities in establishing an AGC link. The project has now resolved this and regulation FCAS has been enabled.
- the LSBS system and solar farm projects have different owners, hence a parent/child metering arrangement had to be established
- locating the connection point for the new asset (battery) behind the existing substation connection point for the solar farm introduced several complexities in both the physical connection and registration arrangements for the assets, including:
  - movement of the point of GPS enforcement and meters for the solar farm
  - redetermination of Distribution Load Factor (DLF) for the solar farm
  - renegotiation of the GPS for the solar farm, considering new requirements such the new Full Impact Assessment (FIA) requirements, and a new commissioning and testing procedure and hold point process to prove compliance with the new GPS.
  - requirement to establish a private registered network which connects both the battery and the solar farm to minimise commercial risk to the solar farm, whilst allowing the battery to be connected in its own right as a stand-alone project and still utilise the benefits of co-location
- significant demand charges – compared to a transmission-connected asset, the Gannawarra project is estimating costs of over $500k per annum for demand charges, but these can be reduced by charging during solar hours to thereby reduce the draw from Distribution Network Service Providers (DNSP)
- inability of the project to make use of the LSBS system for the management of curtailment in a local network due to registration of assets as independent generating units. Since the LSBS system is registered as a scheduled market generator and customer, its operation is via market bidding and centralised AEMO control. Under the existing framework the LSBS system is not able to operate outside of this AEMO dispatch and therefore cannot be independently controlled to manage curtailment caused by local constraints.

4.4 Ballarat Energy Storage System

4.4.1 General

The Ballarat Energy Storage System (BESS) is a standalone 30 MW/30 MWh battery located at the AusNet Services Ballarat Terminal Station in Warrenheip, Victoria. The project was developed by NuvoGroup, with the LSBS system supplied by Fluence using LG Chem batteries and Power Electronics inverters. Equity was raised from AusNet Services and a long-term off-take agreement is in place with Energy Australia.


Department of Land Water and Planning (DELWP) Victoria

4.4.2 Key services

The BESS is designed to deliver three primary services; energy arbitrage, regulation Frequency Control Ancillary Services (FCAS) and contingency FCAS.

4.4.3 Operational status

The LSBS system was commissioned on 30 November 2018. During the first three months of operation, the BESS was dispatched to provide FCAS over 1,400 times, injecting or absorbing power to compensate for excessive drops or rises in frequency on the Victorian grid. The BESS provided three per cent of raise contingency FCAS dispatched in the NEM in Q1 2019.

4.4.4 Innovations

The BESS is the first project of its kind to be built by an Australian Engineering, Procurement and Construction (EPC) company. This is a good indication of growing the necessary skill-sets within the Australian market and will help to develop expertise that can be leveraged for future projects.

In addition, project proponents note that it is the first stand-alone battery-based energy storage asset in Australia (i.e. not co-located), which establishes an important precedent for future systems of a similar type (It should however also be noted that the HPR, for example, while physically collocated with a wind farm was also connected, registered and operated as a standalone system).

For Fluence, this was the first commercial installation of its latest generation Advancion platform.

4.4.5 Project-specific challenges

Generator Performance Standards (GPS) applied to the BESS project as a stand-alone battery system were refined with AEMO through the GPS negotiation and registration process deployment, which added complexity to the GPS negotiations. The project therefore had to establish a GPS precedent to be able to connect to the grid.

Specific challenges encountered by the project include:

- confusion regarding who sets system ramp rate for contingency FCAS (the application of AEMO's Market Ancillary Services Specification (MASS) tool was negotiated with AEMO for the battery to operate with a three second ramp rate). Both the simulation and the FCAS test result demonstrated that the system provided FCAS services within 20 milliseconds of the standard frequency ramp
- development of refined R2 testing requirements for a stand-alone battery, including testing operation as both generator and load
- management of constant parasitic load – the system's auxiliary load is connected via a single revenue meter and the system itself operates exclusive of auxiliaries while the revenue settlement is inclusive of auxiliaries.

Initially, the system would trip if State of Charge (SOC) dipped below three per cent – the Fluence team used the opportunity to update both its training regime as well as its SOC management software to ensure system performance falls within stated guidelines.

4.5 Lake Bonney Energy Storage System

The Lake Bonney Energy Storage System is a 25 MW/52 MWh battery near Mount Gambier, South Australia. The project is owned and operated by Infigen. Batteries were supplied by Tesla, who were also the EPC contractor, supported by Consolidated Power Projects (CPP).


Image: Infigen

4.5.1 Key services

The battery has been developed for direct revenue generation through energy and FCAS market participation, and to firm Infigen's portfolio of solar and wind projects. A firmed portfolio is advantageous to enable additional opportunities for Power Purchase Agreements (PPAs) with Commercial and Industrial (C&I) customers. Infigen also intends to use the battery to reduce its Causer Pays Factor (CPF) and associated costs. Additionally, it will be used to reduce curtailment of generation from the Lake Bonney Wind Farm. This is expected to be relatively straightforward with respect to curtailments caused by network thermal limitations.

4.5.2 Operational status

Lake Bonney is fully constructed, but yet to reach operational status due to issues with the grid connection process which has resulted in a delay of ~6 months to date.

4.5.3 Innovations

Through this project Infigen is seeking to expand upon previously deployed operational strategies to increase the value of revenue streams captured through the battery as an integrated part of its wider renewable generation portfolio. In addition to participating in the wholesale energy market and both contingency and regulation FCAS markets, Infigen has proposed a solution to reduce the co-located wind farm's CPF and associated costs.

Infigen's Operations Control Centre will also work in tandem with the automated bidding software that will be deployed alongside the battery to try and reduce revenue that is currently lost by the wind farm due to constraints in the network. The ideal outcome will be that the battery takes advantage of times that the wind farm is being curtailed by bidding in a way that leads to the battery charging and the wind farm generating more power.

Infigen's innovative solution to reducing its CPF involves reducing the dead band for the battery's contingency FCAS response to within the normal frequency operating band of 50 ± 0.15 Hz. This will enable it to autonomously provide a degree of frequency support within this operating band. Under the Australian Electricity Market Operator's (AEMO's) existing Causer Pays Procedure, this additional support will be included within the calculation of Infigen's CPF across its portfolio of assets and is expected to reduce its total Causer Pays costs. This financial benefit will only be realised when the LSBS system is not enabled in the Regulation FCAS market. The battery's dead band settings will also need to be optimised in consideration of the additional costs of this operating mode due to increased energy throughput and losses.

In terms of revenue estimates, the project is expecting significantly higher revenue from wholesale arbitrage and FCAS than other ARENA-funded projects. The revenue anticipated is also significantly higher than the estimated battery revenue observed through ARENA's benchmarking analysis, due to the context of the battery in the wider Infigen portfolio. Once operational, if Infigen is successful in realising all revenue streams at the estimated levels, the project will present a powerful demonstration that LSBS are moving toward commerciality, when implemented as part of a portfolio to maximise the complimentary value it provides in such a context. The project is expected to demonstrate commercial opportunities specific to integration within a portfolio that would not be available to standalone LSBS projects.

4.5.4 Project-specific challenges

Delay of the connection studies, including Generator Performance Standards (GPS), Full Impact Assessment (FIA) and Essential Services Commission of South Australia (ESCOSA) application were expected but unforeseen to the extent that has been experienced. Lake Bonney was one of the first LSBS in South Australia which had to comply with the new GPS rules (AEMC rule change reference ERC0222), which came into effect in October 2018, and the ESCOSA technical requirements. To meet these specifications, the project had to develop a Power Systems Computer Aided Design (PSCAD) model and go through a full impact assessment in a weak part of the grid, while co-located with an existing wind farm.

5. SHARED INSIGHTS

5.1 General

Based on the information gathered through the data collection phase, needs and recommendations for future LSBS projects have been identified in four over-arching categories; technical, commercial, regulatory, and collaboration. This section considers other LSBS projects in Australia in addition to the ARENA-funded projects and the HPR.

5.2 Technical

5.2.1 Abilities of LSBS projects proven to date

Wholesale energy market participation / arbitrage

Wholesale energy market participation based on energy market price signals is a straightforward application of battery capability and is accessed by all LSBS projects covered by this study.

The wholesale energy market participation strategy can also be tailored to provide additional benefits on some projects when paired with a renewable energy generator. For example, the Lake Bonney LSBS system has the potential to be operated to reduce curtailment of the wind farm through bidding to charge the battery as a market customer during periods of transmission thermal constraints. When a commercially beneficial opportunity arises, this would increase the system load on the wind farm side of the network constraint, thereby enabling additional generation from the wind farm that can be later dispatched from the battery. This operating strategy is intended to be applied through participation of the battery in the existing wholesale energy market and does not require rule changes to implement.

Curtailment management is a potential business case element for other similar VRE projects co-located with LSBS that are subject to network constraints.

Contingency FCAS and Fast Frequency Response

Contingency FCAS is a proven service provided by the HPR, ESCRI-SA and BESS. This involves the LSBS system providing an autonomous dispatch of real power based on an approved frequency droop curve and deviations in the frequency in the power system outside the normal operating band.

The registered contingency FCAS capacities of the LSBS projects are summarised in Table 2.

Table 2: Contingency FCAS registered capacities[5]

Service	ESCRI-SA	Gannawarra	Ballarat	Lake Bonney (intended registration capacities)	Hornsdale
Raise 6 second	30 MW	Not yet registered	30 MW	15 MW	63 MW
Raise 60 second	30 MW	Not yet registered	30 MW	4 MW	19 MW
Raise 5 minute	30 MW	Not yet registered	30 MW	10 MW	41 MW
Lower 6 second	30 MW	Not yet registered	30 MW	15 MW	80 MW
Lower 60 second	30 MW	Not yet registered	30 MW	4 MW	80 MW
Lower 5 minute	30 MW	Not yet registered	30 MW	10 MW	80 MW

5 AEMO "NEM Registration and Exemption List" (accessed 11 July 2019)

The ESCRI-SA and BESS have both been registered in all contingency FCAS markets at their full 30 MW capacity.

HPR has been able to be registered at its full 80 MW charging capacity in each Lower contingency FCAS market but has not been able to register its full 100 MW discharge capacity in each Raise contingency FCAS market. Lake Bonney also intends to register for contingency FCAS at capacities below the actual dispatch capacity of the LSBS system.

The reason for the difference between permissible Raise contingency FCAS registrations, and how the Market Ancillary Services Specification (MASS) has been applied between projects is not clear from publicly available information.

In January 2019 AEMO released a document to define requirements for LSBS contingency FCAS registration[6]. This document defines default contingency FCAS droop settings to be applied for LSBS projects, and the corresponding capacities that can be registered in contingency FCAS markets. This guidance indicates that a LSBS system can be registered in Raise and Lower contingency FCAS markets for up to 41 per cent of its discharge / charge power capacity respectively, rounded down to the closest MW.

Application of this guidance in not consistent with the registered capacities of any of the LSBS projects that have been registered in these markets. As such, there remains some uncertainty as to the potential registered capacities for future LSBS projects in these markets.

Contingency FCAS response times

HPR and ESCRI-SA provide FFR through participation in contingency FCAS markets. FFR is an application of the contingency FCAS service but with much faster response times of typically 100 – 250 ms, as compared to the maximum six second response time required by the 'fast' contingency FCAS markets.

> The capability to provide FFR is standard for battery systems, however its implementation to date has been dependent on project specific requirements, and this "premium" frequency control service is not currently valued beyond the revenue available through the existing contingency FCAS markets.

HPR and ESCRI-SA are South Australian Government and Transmission Network Service Provider (TNSP) sponsored projects respectively, with specific system security objectives. These are also both located within South Australia, where FFR can have additional benefit in certain cases of relatively low inertia on the network. This need is also recognised by the SA Government Office of the Technical Regulator (OTR), which requires new generation projects to fulfil certain inertia and/or FFR requirements to receive development approval.

The BESS project in Victoria also has the capability to provide FFR, however this is not enabled on the project. Application of AEMO's Market Ancillary Services Specification (MASS) tool was negotiated with AEMO for the battery to operate with a three second ramp rate (which is twice as fast as the minimum 6 second response required by the 'fast' contingency FCAS markets). While further details have not been provided on how this three second ramp rate is implemented, Aurecon expects that this is likely to involve applying a ramp rate limit (in MW/s) based on ramping to the battery's full capacity over three seconds. During contingency events the LSBS system would ramp at this rate to its power set point as required by the deviation in frequency and its frequency droop curve.

From these project experiences it seems that implementation of FFR and/or negotiated battery response rates in provision of contingency FCAS may be dependent on National Electricity Market (NEM) region and network needs.

6 AEMO (14 January 2019) "Battery Energy Storage System Requirements for Contingency FCAS Registration"

Regulation FCAS

Regulation FCAS is service available from the HPR, BESS and GESS, and is also intended to be provided by the Lake Bonney LSBS system. Registered regulation FCAS capacities of the LSBS projects are summarised in Table 3.

Table 3: Regulation FCAS registered capacities[7]

Service	**ESCRI-SA**	**Gannawarra**	**Ballarat**	**Lake Bonney** (intended registration capacities)	**Hornsdale**
Raise regulation	Not registered	25 MW	30 MW	25 MW	100 MW
Lower regulation	Not registered	25 MW	30 MW	25 MW	80 MW

Each LSBS project has been able to register its full discharge / charge capacity in Raise / Lower regulation FCAS markets respectively.

Large-Scale battery storage projects (in particular HPR) have demonstrated fast and accurate provision of regulation FCAS. Operational data shows that LSBS can provide very rapid and precise response to AEMO's Automatic Generation Control (AGC) regulation FCAS signals, in contrast to the response of large conventional steam turbines that typically provide the majority of this service in the NEM[8]. The following charts compare the quality of Regulation FCAS typically provided by coal fired generators to the HPR.

The existing regulation FCAS framework does not incentivise or reward the increased quality of this service that can be provided by LSBS.

Battery operation for regulation FCAS requires significantly greater energy throughput than required for contingency FCAS. There are therefore additional round trip efficiency energy losses and degradation considerations that should be incorporated into a regulation FCAS market participation strategy. Due to efficiency losses a battery will tend towards reducing state of charge when providing both raise and lower regulation FCAS, which also needs to be managed.

This can be managed through an intelligent bidding strategy that, for example, takes advantage of periods of low wholesale energy prices to provide lower regulation FCAS, which requires the battery to follow AGC signals to charge only. This enables recharging of the battery over a period of low energy prices while also being paid to provide regulation FCAS.

7 AEMO "NEM Registration and Exemption List" (accessed 11 July 2019)
8 Aurecon (2018) "Hornsdale Power Reserve Year 1 Technical and Market Case Study" Available at: https://www.aurecongroup.com/ markets/energy/hornsdale-power-reserve-impact-study

Figure 1: HPR regulation FCAS response

Network loading control

LSBS projects have the potential to provide a network loading control service to enable transmission elements to be operated within their continuous rated limits, if located in a part of the network that needs this service. This function would be simple for battery projects to provide, however has not been required or applied in any of the LSBS projects commissioned to date. Provision of this service would be based on a Network Loading Ancillary Service (NLAS) agreement with the T/DNSP.

This potential service has not been offered / applicable to any LSBS projects to date.

The System Integrity Protection Scheme (SIPS) is a similar but more advanced scheme developed by AEMO and ElectraNet to protect the Heywood interconnector from tripping. The SIPS is designed to rapidly identify conditions that could otherwise result in a loss of synchronism between SA and Victoria, and to correct these conditions by rapidly injecting power from LSBS and shedding load (if required), to assist in rebalancing supply and demand in South Australia and prevent a loss of the Heywood Interconnector.

Battery projects currently participating in the SIPS are HPR and ESCRI-SA, which are SA Government and ElectraNet sponsored projects respectively, with specific system security objectives. No direct revenue streams are available to battery projects to provide this service.

Fringe of grid islanding

Relative lack of redundancy and additional response times for network repairs can decrease reliability of supply at fringe of grid locations. Battery systems configured for grid forming and micro-grid operation can support reliability of supply for discrete fringe of grid portions of the network.

The ESCRI-SA project in conjunction with the Wattle Point Windfarm has demonstrated this capability and provides this service for the local network. The project provides seamless islanding of the local network in the event of a network outage. In this case, the LSBS system provides the grid forming functionality and has primary responsibility for maintaining the system voltage and frequency within required limits. The wind farm automatically runs back to a level of generation that can be supported by the LSBS system and the local network load, with the LSBS control system issuing generation set points to the wind farm for continued islanded operation.

There is opportunity for future battery projects to provide similar fringe of grid islanding services. It should however be acknowledged that there can be significantly increased technical challenges in enabling this functionality, across issues such as GPS modelling, system strength, protection system operation and integration with other generation.

Voltage control

A LSBS project's GPS will require a certain reactive power capacity to support voltage control in the local network, which is typically required of all generators. It is understood that most of the LSBS projects that are the subject of this report have such reactive capability, although it was advised that the BESS operates at unity power factor (no reactive power contribution). Details regarding utilisation of the LSBS system's reactive power capacity is negotiated with the NSP, and may, for example, require a voltage control coordination deed to define the required LSBS system's response characteristic in conjunction with other assets.

Also included within the NEM non-market ancillary services are Voltage Control Ancillary Services (VCAS). This is a contracted service to provide reactive power to maintain voltage and stability within required limits following a credible contingency event. Provision of this service is subject to a VCAS agreement and is procured as needed by the network.

VCAS can be a service required either to maintain system security or to enhance network transfer. It is dispatched in accordance with a VCAS agreement in conditions in which a market benefit test is satisfied (e.g. compared to a change in generator dispatch to satisfy requirements). Battery systems installed with additional inverter capacity than required to meet minimum GPS requirements could potentially provide a VCAS service if needed on the network.

A VCAS service could potentially be provided by a LSBS system with current source inverters where the network need is reactive power capacity, and very fast response times are not required. If the network application requires fast acting voltage support (such as typically provided through a static synchronous compensator), this could potentially be provided through the fast response available from a LSBS system with voltage source inverters, or comparable parallel operating modes with some current source inverters.

5.2.2 Emerging LSBS capabilities

Simulated inertia

Key challenge(s) – limited number of delivered projects available to demonstrate technology; no market available to monetise this service.

Inertia on the electricity network reduces the Rate of Change of Frequency (RoCoF) during contingency events, which is important in enabling Contingency FCAS service sufficient time to operate, as well as protection schemes as required such as Under Frequency Load Shedding (UFLS). Inertia is inherently provided through the rotating mass of synchronous machines. Some advanced grid forming inverters now also offer a simulated inertia function (and also some current source inverters with a similar parallel operating mode), which provides an equivalent impact on reducing RoCoF, however with a different approach.

Simulated inertia through LSBS involves the dispatch of active power in proportion to the RoCoF at sub-cycle response times, which simulates the inertial characteristic of a synchronous machine in arresting RoCoF.

An advantage of simulated inertia is that the response characteristic is highly configurable through control settings to achieve the desired response.

A disadvantage of simulated inertia from a battery is that it does require sufficient 'head-room' to increase its power output in response to a RoCoF event, which may not always be available depending on other functions the battery is performing.

A potential risk that also needs to be addressed by simulated inertia proponents is the stability of the response and prevention of false triggering of the simulated inertia function to fault events (as compared to contingency events in which inertia is required).

Some battery suppliers have demonstrated simulated inertia in microgrid applications, and it is understood demonstration projects on the NEM are planned. It will be important for such projects to demonstrate this capability and build confidence in stakeholders, including AEMO, of the performance of LSBS in providing this service.

Inertia is not currently a valued service on the NEM. The Australian Energy Market Commission (AEMC) published its Frequency Control Frameworks Review in July 2018, which reviewed the structure of the existing FCAS markets to determine whether they will remain fit for purpose in the longer term as the power system changes. It concluded that the best approach to the procurement of frequency services in the longer-term will need to be performance-based, dynamic and transparent, and included analysis of pricing mechanisms that could incorporate a range of frequency services, including inertia. There is however no clear direction at the present time as to any specific proposed rule changes, or a timeline for their development.

System strength

Key challenge(s) – significant differences in capability of different LSBS inverters to support system strength; further modelling and testing needed to demonstrate capability of high performance inverters to support stable voltage conditions in weak networks; no market available to monetise this service.

With increasing levels of asynchronous Variable Renewable Energy (VRE) displacing synchronous generation, declining system strength has become a major challenge that needs to be addressed. System strength is a measure of the power system's stability under all reasonably possible operating conditions (with the exception of inertia and frequency issues, which are considered separately). It reflects the sensitivity of the power system to disturbances and its ability to remain stable under normal conditions and return to steady-state conditions following a disturbance such as a fault. Most inverter-based asynchronous generating systems require a minimum system strength at their connection point to maintain stable operation under normal conditions and following contingency events.

System strength is inherently provided by synchronous generators, but not by most current source inverters used in VRE generators, or battery systems with inverters configured in current source mode. Some emerging battery inverter technologies have the potential to support improved system strength / 'voltage stiffness' in weak grids in the following ways:

1. enable stable operation of the LSBS system itself at very low system strength
2. voltage smoothing on weak grids, which can help compensate for instabilities caused by a range of factors such as network switching, changes in power flows, voltage flicker caused by current source inverters, and during fault recovery
3. provision of fault current for improved short circuit ratio (SCR) and stability of other current source inverters (VRE generators) during fault or other voltage disturbance conditions
4. improved SCR and adequate fault current for protection operation.

LSBS with voltage source inverters have the potential to contribute to each of the above system strength elements. There is significant variability in LSBS system inverters with respect to their fault current capacity (in the range of approximately 120 – 200 per cent of normal continuous rating), and some manufacturers are seeking to further increase the fault current capacity of their inverters. The higher the fault current capacity of the inverters, the more it can contribute to system strength elements 3 and 4 above.

Traditional current source inverters cannot contribute to any of these system strength elements. While some current source inverters are able to provide a fault current contribution, this is not recognised by AEMO as contributing to the fault level (and therefore system strength requirements) since current source inverters can become unstable during disturbance events involving significant distortions in the voltage waveform. Current source inverters use Phase Locked Loop (PLL) to 'lock onto' the reference voltage waveform of the network. When there are significant instabilities in this waveform, current source inverters can become unstable and may, for example, interact with each other and oscillate against one another. Since this does not apply to voltage source inverters, their fault current contribution can potentially be recognised as contributing to system strength under AEMO's Fault Level Framework.

An emerging battery inverter innovation involves a comparable operating mode in parallel with current source inverter control to provide fast acting voltage support. This can potentially support system strength element 2 above. Modelling would be required to demonstrate that element 1 is also achieved and the LSBS system itself can remain stable connected at very low Fault Levels through the additional voltage stiffness it provides.

Proponents of this operating mode have also highlighted the potential for voltage stability in weak grids to be provided through its fast voltage smoothing function, enabling more stable grid conditions for other current source inverters. This would be an alternative approach to achieving the system strength objectives delivered through the AEMO's Fault Level Framework. While providing sufficient system strength in terms of Fault Level addresses the underlying cause of voltage instability, a fast-acting voltage smoothing function attempts to correct the instability once it occurs. Sufficient installed capacity of this fast-acting voltage service may potentially enable acceptable voltage stability for stable operation of current source inverters in weak grids, however this needs to be further proven through modelling and demonstration.

There is no existing market framework for provision of system strength. This service is best valued through incorporating it into the business case for a new VRE generator for which the system strength impact assessment identifies a shortfall that can be met through a battery with capability to support system strength. In this case the battery could enable a project to proceed in lieu of other system strength remediation mechanisms such as synchronous condensers, while also providing other more standard battery services.

There is no existing market framework for provision of system strength. This service is best valued through incorporating it into the business case for a new VRE generator.

Due to the complexity involved in evaluating a LSBS's contribution to each element of system strength, the system strength needs at particular connection points, the relative immaturity of LSBS providing this service and the range of inverter capabilities available in the market, there remains considerable uncertainty among stakeholders regarding whether, or the extent to which, LSBS can support system strength.

Grid formation

Key challenge(s) – emerging technology requiring further development and modelling to demonstrate capability to provide grid formation on large networks with low (or potentially no) synchronous generation.

In addition to the potential inertia and system strength benefits of grid forming inverters, they can be of particular benefit in a large power system if it is operating with a high penetration of VRE generation and is islanded from another region. For example, LSBS with grid forming inverters could potentially support a stable operating system in South Australia if it is islanded from the other NEM regions. Significant additional modelling and proof of concept is however required to demonstrate the capability of large power systems to operate islanded, supported by a high portion of grid forming inverters.

System restart ancillary services

Key challenge(s) – requirement of service (to reserve capacity) not currently economically viable / competitive for LSBS technology

Grid forming LSBS have the potential to provide System restart ancillary services (SRAS). Following a system black event, the LSBS system would start in voltage source mode as a virtual generator and form an island behind an open breaker, operating at zero-export for a specified period. The LSBS system would energise the required High Voltage (HV) transmission lines and transformers throughout the restart sequence, maintaining power quality and balance supply and demand. It would then typically provide the auxiliary power supply for start-up of another generator such as a gas turbine.

While this service can be provided through a battery, there are significant challenges in doing so, namely:

- the LSBS system's capability to energise the required HV transmission lines and transformers throughout the restart sequence needs detailed power system studies review
- energy storage capacity would need to be reserved for SRAS, and therefore be unavailable for other functions (such as arbitrage, FCAS etc.). The comparative economic return for reserving this battery capacity is unlikely to be an attractive use of the LSBS system compared to deploying it for other functions. It is also unlikely to be competitive with other SRAS technology options such as diesel generators used to start a gas turbine
- an SRAS agreement would only be possible following demonstration of capability and there would therefore be uncertainty in securing this as a revenue stream during the project development phase.

Apart from providing a primary SRAS service as described above, LSBS also have the capability to provide system restoration support services, for example by contributing to voltage control. Reforms to recognise the role of other participants in providing system restoration support is underway and there may be potential for battery projects to realise additional value through such services.

Causer Pays cost mitigation

Key challenge(s) – grid connected LSBS (>5 MW) unable to provide this service directly under current regulatory framework; alternative portfolio level approach to providing this service to be demonstrated

As previously noted, generators are liable for a Causer Pays cost associated with deviations from their dispatch targets and the procurement of Regulation FCAS to compensate for this.

Small battery energy storage systems of less than 5 MW could potentially be installed behind the meter in conjunction with VRE generators to directly firm the dispatch from the generator to avoid / minimise deviations from dispatch targets. Battery energy storage systems greater than 5 MW would need to be scheduled generators under the existing LSBS registration framework and would not be able to directly provide this service. This may however be addressed under the proposed new Bidirectional Resource Provider registration category.

As also noted above, in 4.5.3, Infigen have proposed another innovative approach to reducing their Causer Pays exposure across their generation portfolio. This approach could also be investigated by other holders of significant VRE portfolios.

Primary frequency control

Key challenge(s) – increase in round trip efficiency losses and degradation to provide this from batteries

Primary frequency control is a service that could enable batteries to support maintaining frequency within the normal operating range. This would involve batteries operating with a tightened frequency droop deadband and deploying their FFR capability to respond to small deviations in frequency within the 50 ± 0.15 Hz normal operating range. A challenge in providing this service from batteries is the additional cycling of the battery, with associated increase in round trip efficiency losses and degradation.

Following frequency control test trials in Tasmania by Hydro Tasmania, AEMO and TAS Networks[9], AEMO is continuing to develop an interim and longer-term strategy to improve frequency performance in the NEM in accordance with the Work plan for frequency control in the NEM as set out in the AEMC Frequency Control Frameworks Review[10]. This includes completing a trial of revised primary frequency control in the mainland, building on experience from the Tasmanian trial.

Providing they do not wish to normally operate at their Maximum Continuous Rating (MCR), this is a relatively inexpensive service for traditional generators to provide. Operating costs to use batteries for primary frequency control are primarily due to energy losses and additional degradation from increased energy throughput. This may however be a future service that batteries can provide with increasing VRE and declining thermal generation.

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9 F&M Ringrose Pty Ltd (12 December 2018) "Tasmanian Frequency Control Tests: Summary Report"
10 AEMC (26 July 2018) "Frequency Control Frameworks Review"

Market bidding optimisation

Key challenge(s) – significant room for improvement in sophistication of bidding optimisation tools from a variety of suppliers

Optimal LSBS energy market participation is ideally through a bidding optimisation algorithm that generates optimal bids in each market for which the LSBS system is registered (e.g. wholesale energy market as both a scheduled generator and load, and all eight FCAS markets). This should consider a range of factors, including price forecasts for each market, battery state of charge management, operational losses, battery degradation impact, and any other constraints such as energy reservation for other required services, such as:

- hedging products
- VRE firming obligations under a PPA
- network constraint management / peak shaving
- demand charge management for behind the meter commercial and industrial customers.

The Tesla Autobidder system has been successfully deployed on the HPR and is considered the most advanced optimisation system currently in service for LSBS projects on the NEM, although other developers and technology providers are also developing such bidding optimisation software.

> Deployment of well-developed and customised bidding tools will be key to maximising potential revenue streams and the commercial returns for battery projects in a complex energy market, noting that the level of complexity may continue to increase through the addition of new markets or incentive mechanisms for additional services.

5.2.3 Key areas for further development

The following are some key areas for further development of battery systems to maximise the potential for their deployment to address network challenges and provide stakeholders the information and confidence needed to develop such projects and improve.

Simulated inertia

As noted above, grid forming batteries (and some current source batteries with similar parallel operating modes) have the potential to provide simulated inertia. Further demonstration of this capability and development of learnings regarding benefits and mitigations of potential risks is needed to build the confidence needed for simulated inertia to be recognised as a viable alternative. Such learnings may also inform an appropriate market structure for the procurement of such services.

System strength

System strength is a multi-faceted term, and different battery inverter technologies offer a range of capabilities to address different elements of the system strength equation.

Some suppliers are developing grid forming inverters with significantly higher fault current capacity than other inverters, and these have the potential to provide improved support for some system strength elements. Such technology developments should be encouraged.

The capabilities of different battery inverters to provide system strength support needs to be further understood by project developers in assessing the potential of different technologies to provide the support needed for particular project applications in weak grid locations.

The relative system strength benefit of high performance battery inverters compared to synchronous condensers is another issue that needs further examination to provide developers the information needed to make informed strategic decisions as to how best to address system strength shortfalls.

Power system modelling

Better modelling is needed of the capability of inverter-based generation and storage to support system security and stability as the penetration of asynchronous renewable generation reaches and exceeds 50 per cent.

The outcome of such modelling would be highly dependent on the modelled inverter capabilities, noting the range in capabilities available from different suppliers. Different scenarios modelled with different inverter capabilities may also offer technology providers guidance as to the level of performance that would be required and should be developed for future scenarios involving very high penetrations of asynchronous generation.

Bidding algorithms

As noted above, deployment of well-developed and customised bidding tools will be key to maximising potential revenue streams and the commercial returns for battery projects in a complex energy market. Significant development is needed in this space. Technology supplier agnostic options that can be applied and customised for different battery suppliers would significantly enhance the ability of different battery suppliers and LSBS system integrators to compete in this space.

Flexible warranties

There is a significant range in the flexibility of warranties offered by different battery suppliers. While some suppliers offer flexibility in the use of the battery, with levels of guaranteed degradation applying based only on the energy throughput and age of system, other battery suppliers do not yet offer significant flexibility. Standard warranty conditions offered by some battery suppliers may be based on a set of standard energy cycling and state of charge assumptions, which are unlikely to accurately reflect the operation of the battery in a complex market.

Further development in frameworks that enable warranty flexibility is needed to both protect battery suppliers from the degradation risks involved with different use cases, while also enabling battery operators the flexibility to optimally operate the battery based on project specific criteria in a complex market.

Degradation management and battery project life

Different strategies are available with respect to degradation management and project life extensions. Batteries are often considered to have a nominal 10-year life, whereas the project life considered for wind and solar PV projects is typically 20 – 25 years.

It is evident that further development of options to extend LSBS projects beyond a nominal 10-year period will improve business cases and provide project developers with a better array of options with respect to how to manage life extensions for battery projects.

It should also be noted that it is only the batteries / battery modules themselves that are actually subject to this relatively short design life. Other project expenses, including inverters, enclosures, switchgear, transformers, control systems, civils, grid connection and other balance of plant can have an extended design life.

The following are the general strategies that can be considered for battery life extension:

- initial battery life of nominally approximate 10 years, followed by performance and condition assessment to determine strategy at that point, potentially involving extending battery life or replacement
- a degree of warranty flexibility in the initial agreement that can enable nominally up to approximately 5 years warranty extension subject to usage in the initial warranty period
- capacity maintenance / upgrade agreement in which the battery supplier is contracted to upgrade batteries as required to maintain a minimum capacity throughout the project life (e.g. up to 20 years).

Not all options are well supported by all battery suppliers and it is considered that the industry needs to further develop extended warranty options. This should be done in conjunction with flexible warranties as described above to enable projects to be developed with improved confidence in project life and associated costs and performance.

Decentralisation and islanding

Decentralisation is being witnessed not just in community projects but also in the development of microgrids for future developments, to improve reliability for fringe of grid applications, and to enable a high penetration of VRE in isolated networks.

Different challenges emerge at different scales of islanded networks, also depending on the penetration of and nature of asynchronous generation on the islanded network. Understanding of how battery storage can support increasing levels of islanding at various scales of islanded network, including up to a state level (e.g. in the event of separation from the remainder of the NEM) would aid the development of high VRE decentralised and islanded networks.

Increased modelling to demonstrate the capability of advanced inverter technology to support reduced reliance on synchronous generation would aid the development of such projects, build confidence in the viability of such projects, and potentially deliver insight to technology providers regarding key areas for further development.

5.2.4 Other technical learnings from ARENA funded projects

The following are some other points that have emerged from stakeholder engagement of funded projects:

- auxiliary power consumption
  - some projects have experienced higher than expected auxiliary power consumption and standby losses. There may be scope for further development and optimisation of balance of plant such as battery container HVAC systems and their control systems to minimise auxiliary power consumption.
- commissioning and grid connection
  - some projects experienced delays in commissioning due to challenges with the timing of grid connection access being granted. While this has been highlighted as a specific challenge for standalone battery projects, this is also typically a common issue for battery systems co-located with generation since they cannot use these generators to form a micro-grid for battery commissioning and testing
  - mitigations available include using temporary equipment such as diesel generators and a load bank if necessary to energise the system for commissioning. Provisions would be needed for connecting this temporary equipment. These considerations may be warranted for projects in which network access in advance of commissioning is identified as a significant risk.

5.3 Commercial

5.3.1 Proven revenue streams

As already described in this report, there are a range of proven and emerging capabilities and services offered by LSBS. Monetising these services and deriving secure revenue streams for a business case however, continues to be one of the biggest challenges for the battery market. As the market evolves, so too will the number of reference projects, leading to growing investor confidence and a better appreciation for the risk profile associated with this emerging technology. Greater certainty and predictability of revenue streams will also improve as more projects reach operation, and there is successful demonstration of different use cases in the market.

To optimise revenue, LSBS projects are designed to monetise multiple services in parallel i.e. "value-stacking". Commercial demonstration of these revenue streams coupled with cost reductions in equipment and installation are likely to provide the best opportunity for batteries, and this will only come with supporting new projects as the technology class moves toward full-scale bankability.

Table 4 outlines the key services and revenue streams for each of the ARENA-funded LSBS projects, as well as HPR. There are three common revenue streams: Wholesale energy market participation; Regulation FCAS; and Contingency FCAS. The ability to accurately forecast revenue from these services however, continues to be a challenge for LSBS, since the ability to capture revenue is uncertain due to the reliance on fluctuating spot prices, FCAS price signals, and material future changes to the forecast energy system, such as the impact of the changing generation mix and new interconnection projects.

The five-minute settlement period rule change (due to come into effect July 2021) is expected to improve the potential wholesale energy revenue opportunities for batteries, by providing "*better price signals for investment in fast response technologies such as batteries, new generation gas peaker plants, and demand response*"[11].

11 AEMC (28 November 2017) "Five Minute Settlement: Final Rule Change" Available at: https://www.aemc.gov.au/rulechanges/five-minute-settlement

Table 4: Key Services and Revenue Streams

Service	ESCRI-SA	Gannawarra	Ballarat	Lake Bonney^	Hornsdale
Wholesale energy market	√*	√	√	√	√
Regulation FCAS		√	√	√	√
Contingency FCAS	√		√	√	√
System Security (no direct revenue)	SIPS FFR	Planned but not yet registered			SIPS FFR
Other (no direct revenue)	Reduced unserved energy when islanded Islanding			Causer Pays Factor Curtailment Management Firming for C&I customer PPAs	

^Planned services but not yet registered
*Storage capacity limits provision of these more energy intensive services

The Lake Bonney project is highlighted particularly in this report as innovative in terms of the number of revenue streams that Infigen is seeking to capture. The potential expected value realised by Infigen is aided by the expected complimentary "portfolio effects" of a battery operating in the same market as its pre-existing generation and retail contracting portfolio. If the battery were operated by an entity that did not have those additional portfolio consideration (and potential opportunity), the expected value from the unit would likely be substantially lower. Once operational, if Infigen is successful in realising all revenue streams at the estimated levels, the project will present a powerful demonstration that large-scale batteries are moving toward commerciality.

Figure 1 provides an overview of the revenue capture breakdown for each of the ARENA-funded projects. Figure 2 presents the same data to demonstrate the spread across each revenue stream. What these figures show is the wide variability in the business cases of each battery project, indicating that the market is yet to land on the best way to value battery services.

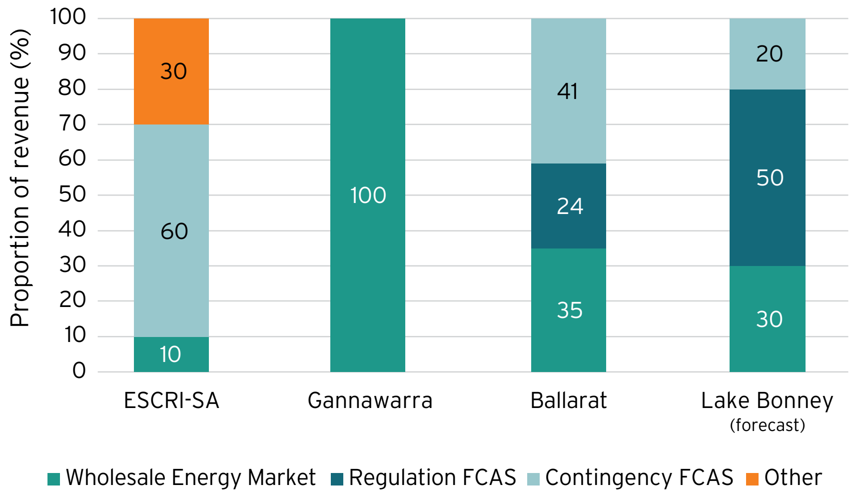

Figure 2: Revenue Capture of each ARENA-funded project[12]

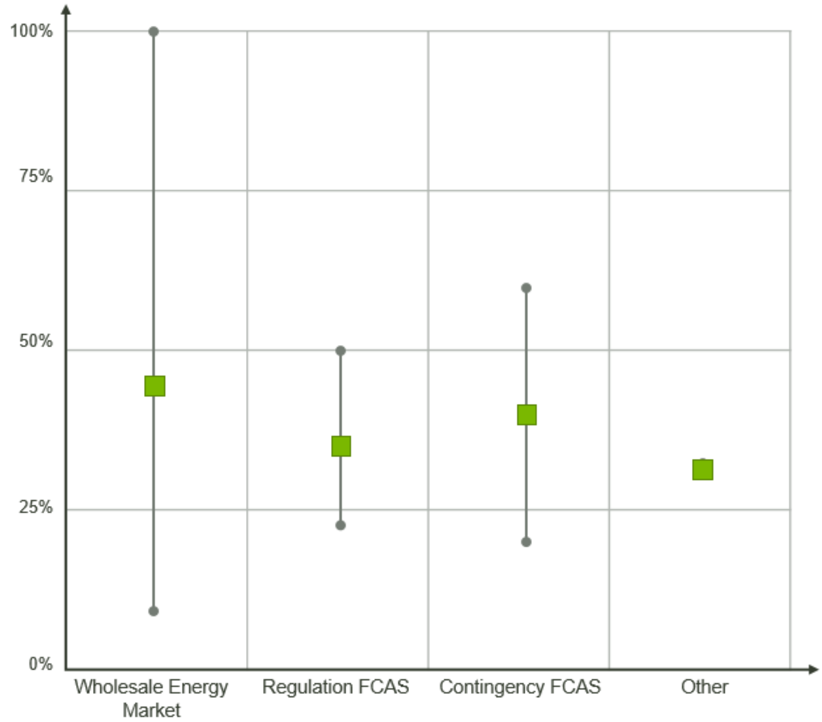

Figure 3: Current Revenue Capture

Given the significance of the FCAS revenue stream for LSBS projects, it is important for the industry to recognise that this market is not limitless. The current FCAS markets are small (210 – 220 MW for regulation; and roughly 350 – 450 MW for contingency), hence a relatively small number of LSBS projects could quickly saturate the FCAS supply markets. The introduction of HPR has significantly increased competition in the Regulation FCAS market. This has effectively reduced the pricing impact of the South Australian 35 MW FCAS constraint, which is estimated to have added nearly AUD 40 million in regulation FCAS costs in both 2016 and 2017[13]. That being said, as shown in Figure 3, AEMO is anticipating the Regulation FCAS market to grow proportionally in relation to the penetration of utility-scale solar generation (and to a lesser degree, wind generation). So, although there is a limit to the depth of these markets, they are expected to grow over time. The potential growth in market volume is however considered unlikely to offset the downward pressure on FCAS prices (and subsequent revenue available to FCAS providers) due to increased competition for these services.

12 ESCRI-SA Identifies Network Support Payments as the 30 per cent "Other" revenue contribution. Regulation FCAS has only recently been enabled for Gannawarra, so current data shown in chart is not representative of long-term expectations for revenue split.

13 Aurecon (2018) "Hornsdale Power Reserve Year 1 Technical and Market Case Study" Available at: https://www.aurecongroup.com/ markets/energy/hornsdale-power-reserve-impact-study

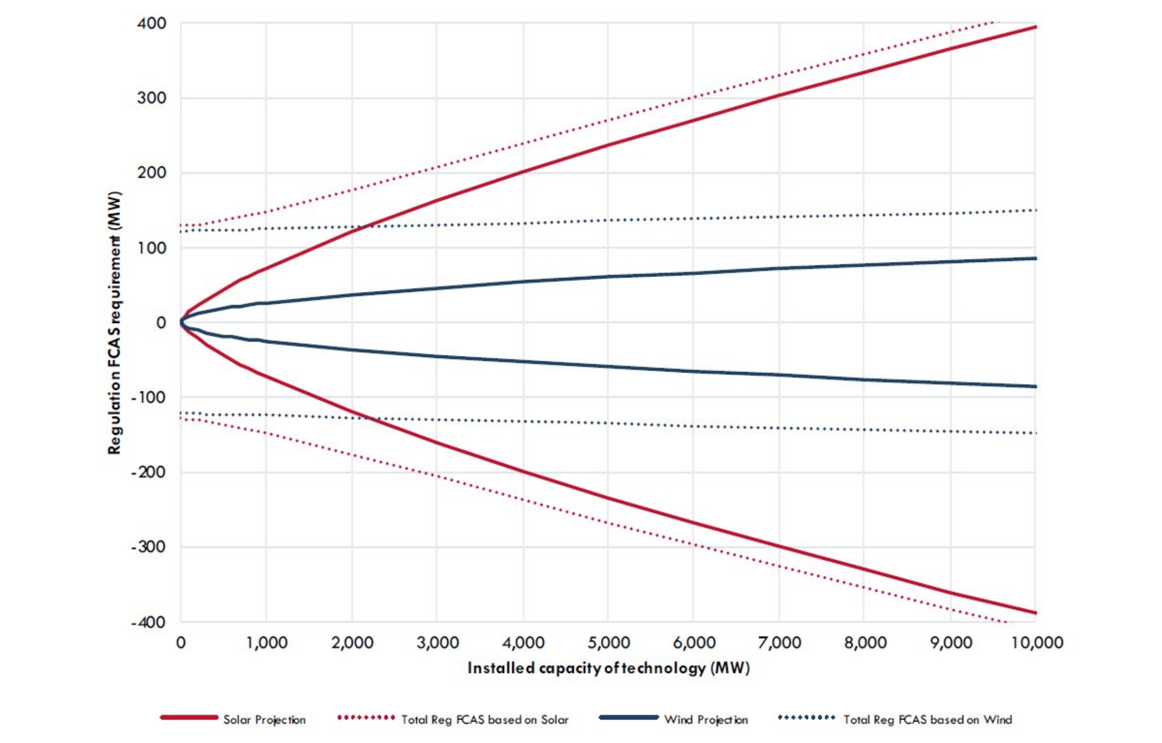

Figure 4: Projected FCAS requirement for increasing penetration of solar and wind generation
Source: Integrated System Plan, AEMO, July 2018

5.3.2 Un-tapped revenue streams

All the ARENA-funded LSBS projects identify additional services that the battery and/or inverter is (or could be) capable of providing that the market doesn't currently pay for. These are summarised in Table 5 below and include services such as: FFR; synthetic inertia; and SIPS. If these additional revenue sources could be accessed by LSBS projects, this would enable additional revenue streams to support future business cases.

It should be noted that these services are not guaranteed for all systems and reference should be made to Section 5.2 for further technical details.

Table 5: Untapped Revenue Streams

Service	Existing revenue stream	No revenue stream
Wholesale energy market	✓	
Regulation FCAS	★	
Contingency FCAS	★	
SIPS		✓
FFR		✓
Synthetic Inertia		✓
System Strength		✓
System Restart	✓SRAS	
Voltage Support	✓ VCAS	
Curtailment Management	✓	
Causer Pays Factor	✓	

★ "premium" LSBS service ✓ existing LSBS service

Regulation and Contingency FCAS – LSBS projects are already providing services in all of the available regulation and contingency FCAS markets. However, despite the LSBS technology offering a much more rapid and precise FCAS response compared to traditional steam turbine generators, both generator responses are valued equally within the current markets. Increased deployment of such high-quality Regulation FCAS would assist in maintaining frequency within the normal operating band, and there is an opportunity for the market to incentivise this.

System Integrity Protection Scheme (SIPS) – SIPS is specific only to South Australia at the present time, however similar schemes to protect other interconnectors could be implemented in future. Battery projects currently participating in the SIPS are HPR and ESCRI-SA, which are South Australian Government and ElectraNet sponsored projects respectively, with specific system security objectives.

Fast Frequency Response (FFR) – As already mentioned, LSBS projects have identified a capability to respond much faster (response times of typically 100 – 250 ms) than is required by the minimum six second 'fast' contingency FCAS markets. The AEMC has already identified this as a potential market reform, "consider…how to most appropriately incorporate FFR services, or alternatively enhancing incentives for FFR services, within the current six second contingency service[14]" and is continuing to "*assess the need for fast frequency response and, if there is a need, the most efficient means to procure that service*"[15].

Synthetic Inertia – Like FFR, the provision of "synthetic" inertia by non-synchronous generators is a topic currently being explored by the AEMC, including options to facilitate co-optimisation of energy, FCAS, and inertia. As more synchronous generators retire, the need for synthetic inertia will increase hence there will be growing pressure for a mechanism to incentivise this as a service.

System Strength – Increasing numbers of VRE developers are reporting cost impacts due to an emerging requirement to install synchronous condensers as part of the grid connection application process. Some battery systems can be designed with inverters that have the ability to provide this service, hence even if the market is unable to offer a direct revenue stream for this service, there is an opportunity for LSBS to support the business cases for VRE generators, particularly where system strength impact assessments identify a shortfall. The capability for advanced grid forming inverters to provide this service does however need further demonstration to build confidence among stakeholders as to the viability of this solution.

System Restart Ancillary Services (SRAS) – technically possible however no batteries registered for this currently. Due to the need to reserve energy to provide this as a service, this particular value stream may not stack up in a LSBS business case when compared with other revenue streams. Reforms to recognise the role of other participants in providing system restoration support (apart from a primary SRAS service) may however enable some battery projects to realise additional value through such services.

Voltage Control Ancillary Services (VCAS) – although technically possible, provision of this service is complex (dependent on local network needs and negotiated agreements with the NSP) and additional inverter capacity above typical GPS requirements would likely be required.

Simplification of the way SRAS contracts (and other Network Support and Control Ancillary Service (NSCAS) contracts) are awarded may enable these potential revenue streams to be recognised more readily by LSBS business cases.

Curtailment Management – Opportunities need detailed project specific assessment.

14 AEMC (27 June 2017) System Security Market Frameworks Review
15 AEMC (26 July 2018) Frequency Control Frameworks Review

5.3.3 Contracting complexity

A number of LSBS projects have reported highly complex contracting arrangements, with sometimes up to 15 parties involved. Due to the complexity of these arrangements it is important that future LSBS project proponents and developers:

- do not underestimate the timeframes for negotiations and contract establishment
- avoid multiple iterations of contracting structures – modifying contracting arrangements and the necessary review/approval process can be protracted
- fully understand the project's business case before establishing the guarantee structure, and any related financial penalties / rewards, and
- leverage from market learning and guidance around how to structure contracts and agreements.

Nested projects, such as Gannawarra, introduce additional complexity due to having multiple owners of one integrated system but the precedent for this has now been established within the market.

5.3.4 Commercial Opportunities

There are a range of opportunities for the market to mature / augment as already described within this section. Besides submitting rule change requests to the AEMC, these are largely outside a LSBS developer's control. There are however a number of considerations and opportunities for developers, as follows:

- consider how to partner with VRE generators, strengthening potential revenue streams, such as behind the meter storage to support curtailment management and Causer Pays Factor management, or via adjustment to LSBS system frequency droop dead band settings for support of reduced Causer Pays factors across a generation portfolio, as proposed by Infigen for the Lake Bonney project and described in section 4.5.3 above
  - over time, build revenue certainty for these value streams for use in business cases
- when developing the business case, ensure there is a clear definition of the end user of the project, and understand their motivations for investment
  - in addition, when preparing funding applications, developers should consider how to better demonstrate their project's ability to achieve/support strategic objectives
- to maximise the through-life value of the battery and extend End of Life (EoL), model different operating profiles to understand how these impact on degradation of the LSBS system
  - in addition, explore how the value of a battery at EoL may be estimated, and even insured, at Beginning of Life (BoL) including which components determine EoL, refurbishment opportunities, and how this may inform new business cases
- explore performance guarantees to facilitate unique contracting mechanisms that focus on reliability at critical times rather than annual availability e.g. optimise maintenance strategies to enable higher availability during the peak summer period. If possible, build this into financial models to strengthen business cases
- fixed demand charges based on a commercial and industrial (C&I) customer's maximum electricity demand can be a very significant element to the tariff for C&I customers. Batteries can be used to reduce distribution network demand charges for such large energy consumers by reducing their peak demand from the network by discharging to maintain the net load within reduced maximum demand limits.

5.4 Regulatory

While industries often look to regulatory reform to solve teething issues, it is important to understand where regulatory reform stems from, and what the end goal is, rather than looking at reform in a piecemeal manner to solve point-in-time issues.

From the data gathered, it is clearly expected by industry that both Federal and State Governments in Australia will continue to focus on the reduction of greenhouse gas emissions as a core objective. This supports the perceived need for an energy transition away from fossil fuels. The projected retirement of 70 per cent of current generation fleet by 2035, due to this energy transition, remains a large challenge for the industry and projections forecast that there may be energy supply shortfalls on the hottest days in Victoria as early as 2022[16].

16 AEMO (August 2018) 2018 Electricity Statement of Opportunities

Through this transition, it is important that diversification of the dispatchable electricity supply is achieved, in order to build a secure and reliable network. This is an area where LSBS can be called upon to support other technologies on a case by case basis and also to provide direct services into the grid.

In addition to large-scale decarbonisation, State Governments have a number of grant programs (e.g. SA Home Battery Storage Scheme, VIC Solar Homes Package) which are turning their attention to community energy projects with the aim to improve energy affordability and efficiency.

> Gaining clarity around the future of regulation and the NEM will assist LSBS projects to develop better financial forecasts, thus providing increased confidence to investors in their approach for valuing services.

5.4.1 Current issues

Through the analysis, several recurring areas have been identified which relate to scenarios where current regulation, written for a legacy system, are hindering progress even in these early stages of LSBS development.

LSBS are currently required to register both as a generator and a load under the current National Electricity Rules (NER). This poses several complexities for LSBS system operation including complicated registration and participation arrangements, and restrictions in the ability to dispatch large batteries for functions such as firming of VRE dispatch to manage Causer Pays factors.

The ongoing work by AEMO to facilitate bi-directional resource participation as part of the Emerging Generation and Energy Storage – Grid Scale work program should resolve these issues and clarify the best way to approach hybrid registration of a LSBS system and VRE generator(s) to reduce complexity. There are however a range of issues that need careful consideration in the design of this new registration category to ensure operational flexibility is maintained for both the VRE generator, LSBS and the hybrid systems. This should include consideration of a standard approach, and clarity around the issues faced by Gannawarra, when connecting a battery to a dedicated asset substation for an existing renewable generation plant, as this is likely to become more common as renewable penetration increases.

Participants have noted that strong collaboration with AEMO during the grid connection process can streamline elements of the process and ensure that any issues arising (particularly in non-standard developments such as standalone, unmanned systems) are approached with pragmatism. Due to existing precedents, this issue may decrease over time, as standard interpretations of the rules for batteries are developed.

While the grid connection process itself is still catching up with the nature of new technologies and how they participate, there is an additional issue of visibility of proposed projects. This impacts the planning of other projects as constraints on the network at the proposed point of connection cannot be evaluated properly at early stages of development. This has been raised not only by LSBS projects but other generation projects and is currently being addressed by the AEMC rule change process. It is expected that a final determination on the transparency of proposed grid-connected developments will be issued in October 2019.

Similarly, the lack of long-term certainty for Marginal Loss Factors (MLFs) continues to erode confidence in revenues and investment viability for projects. This is not unique to LSBS projects, and the current MLF rule change request seeks to provide clarity for existing generators and developers.

The final impact identified is that although the industry is in a transitional period, it is important that a long-term strategy is set out to enable developers and networks to reduce the long-term risks of the bankability of their revenue streams in LSBS projects and ensure that the best projects are being deployed for long-term network support.

As LSBS projects and technologies begin to mature, there are several areas of current regulation that are foreseen as restraining development in certain areas. While the industry wants to see regulatory frameworks that allow the utilisation of LSBS projects, it is of course paramount that such frameworks remain technology agnostic and focus on the desired outcomes, rather than desired solutions, to fully support innovation in the energy sector. Any proposed regulatory changes must ensure consideration for how decisions made now may limit or impact future services and other generators in the NEM.

As outlined in previous sections of this report, even the early LSBS projects are technically capable of providing more services than they currently are used for. This is largely due to a lack of revenue tied to such services. Augmentation of the existing markets, to enable value streams recognised by networks to be monetised, (e.g. FFR, NSCAS services, fringe of grid islanding, SIPS in South Australia) will be critical for the ongoing maturity and commercialisation of LSBS business cases.

Furthermore, as we see further decentralisation of generation in the NEM, it is important to understand how policy will affect such transitions. Different approaches to the deployment of LSBS batteries will be possible, and even necessary, depending on whether decentralised generation will continue to grow and be supported, or whether re-centralisation will be sought.

The need for clear State Government energy strategies

While affordability continues to be the core objective for state governments in their development of policy and strategic frameworks, network reliability also remains a strong focus. This offers only a very broad understanding of the strategy at a state levels but to effectively identify opportunities and develop LSBS projects, it is important for developers to understand the state networks needs at a more granular level.

All three State Governments at the ARENA LSBS workshop highlighted the importance of a clear 'state based' plan, clarity of policy needs, and a focus on strategy. This will help the market to identify "critical" projects to support the NEM – enabling agencies like AEMO to prioritise reviews and approvals based on projects' criticality, in order to ensure the most beneficial projects get built, rather than the first in line.

To understand and communicate the needs, there is a requirement for the continuation of State Government facilitation of industry and federal engagement. This will enable States to effectively achieve their energy objectives and resolve challenges which arise.

To capitalise on this, there is a need for consideration by developers of how to demonstrate their project's ability to achieve/support strategic objectives. This is currently an issue in the approval/uptake of projects and can greatly help to organise the pipeline of projects which are starting to appear.

5.4.2 Opportunities for regulatory reform

Through analysis of the gathered data, a number of specific recommendations for regulatory reform have been identified, and can be summarised as follows:

- address affordability by promoting competition to put downward pressure on energy and ancillary services prices via new entrant 'generators'
- develop frameworks designed for emerging technologies, such as:
  - battery and hybrid generation and storage registration (being addressed through AEMO's proposed bi-directional resource registration category, however detailed design is key)
  - recognition for FFR performance
  - potential new markets for additional ancillary services e.g. FFR, simulated inertia, system strength as a service
- develop a checklist for developers that highlights key points to address with AEMO (and whether early engagement is needed), to help smooth the development process, particularly regarding grid connection
- tariff reform for distribution connected batteries
- fit for purpose operational obligations for remote controlled facilities
- more flexible operating envelopes / fewer operating restrictions where possible
- new GPS, Full Impact Assessment (FIA) process and ESCOSA technical guidelines to help both developers and NSPs to streamline the grid connection process.

Irrespective of the future regulatory reforms that are pursued, in-depth consultation during the process will avoid rushed decision-making and help to mitigate any resultant impacts on investor confidence.

Improvements already being explored

AEMO is conducting a number of reviews in the context of the changing energy system and its future needs, including:

- an investigation of high-RE scenarios
- emerging Generation and Energy Storage – Grid Scale work program
- distributed energy resource work program, and
- contributing to the AEMC Forward Market and ESB post 2025 Market Design work programs.

In addition, the following AEMC rule changes are currently undergoing review and stakeholder feedback:

- transmission Loss Factors (requesting changes to the MLF methodology)
- five-minute settlement period rule change (due to come into effect July 2021), and
- transparency of new projects (final determination expected to be issued in October 2019).

5.5 Learning and Collaboration

In an emerging market, it is important that organisations in the sector do not become isolated, but rather build a collaborative community and leverage the knowledge being developed through the projects which have been completed to date. This will not only help to bring about project success but also ongoing growth for the market as a whole.

The HPR is an excellent example of how strong collaborations between different stakeholders can support tight timeframes on LSBS projects. ESCRI-SA has also identified strong collaboration and stakeholder management as a key driver for the project's success.

While a portfolio of LSBS projects is being built in Australia, looking outside the Australian market for expertise and experience can help to build a more robust project team, though knowledge of the Australian market remains critical.

It is recognised that there is a need for:

- continued knowledge sharing in the industry – to facilitate energy transformation success, and
- continuation of State Government facilitation of industry and federal engagement – to effectively achieve their energy objectives and resolve challenges.

In addition to collaboration on specific projects, there is an opportunity to support growth of the knowledge base with additional frameworks and technical guidelines. A couple of examples of this, which have been suggested by the industry are:

- technical guidelines for ESCOSA assessment, particularly in relation to system strength, and
- an improved framework for Full Impact Assessment, to establish standard practices and streamline processes.

6. CONCLUSION

Large-Scale batteries are an important technology for providing reliability and stability in a high renewable electricity system, as is being developed in Australia. While the LSBS industry is in its early stages in Australia, the batteries which have been developed to date represent a variety of technical and commercial cases.

The projects which have been successfully completed have identified a range of lessons and opportunities to strengthen business cases and regulatory interpretations for future LSBS projects. The key revenue streams of these projects are wholesale energy market participation, regulation FCAS and contingency FCAS. These have been achieved, or soon will be, across the four ARENA co-funded LSBS projects; Ballarat, Gannawarra, ESCRI-SA and Lake Bonney.

LSBS in Australia have also proven their ability to provide other services for voltage control (i.e. ESCRI-SA islanding), system integrity and portfolio causer pays reduction which, in some instances, can be monetised but are not major revenue streams for any LSBS projects to date.

Early movers in the LSBS space have found numerous commercial, technical and regulatory issues which are holding back the development of the market. For example, the development of revenue streams for services such as FFR, SIPS, system strength and synthetic inertia would open up new opportunities to monetise services for batteries that do not currently exist.

There is also a need for clear energy policy and strategy at a state level to help LSBS projects improve bankability of revenue streams by providing them with certainty around which battery services will be valued, and how, over the lifetime of the batteries (typically around 10 years).

Regulation in the National Electricity Market needs to evolve to readily facilitate the development of new LSBS projects. Interim arrangements have enabled the connection and registration of existing battery projects, however revised, fit-for-purpose regulation will further support the range of project types and business models that are emerging for battery storage systems. Several important rule changes are underway which will enable greater participation of energy storage systems in the NEM.

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The following presentations from the ARENA LSBS Knowledge Sharing Workshop on 21st May 2019:

26. Trading Large-Scale Batteries – Our learnings so far, Energy Australia, Daniel Nugent, Stuart Hillen
27. NSW Emerging Energy Program, NSW Government Planning and Environment, Samantha Christie
28. ARENA Big Battery knowledge sharing workshop, Victoria State Government Department of Environment, Land, Water & Planning, Gabrielle Henry
29. Energy Storage (ES) Project Development … the New Frontier, RES Group, Steven Reid
30. Hornsdale Power Reserve – Year 1 Technical and Market Impact Case Study, Aurecon, Steve Wilson
31. Advanced High Power Grid Forming Inverters, ABB Australia,
32. Lessons from the Ballarat Energy Storage System, Fluence, Jaad Cabbabe
33. Potential opportunities for batteries in a high renewable electricity system, AEMO, Chris Davies

APPENDIX 1 – ELECTRONIC SURVEY TEMPLATE

LARGE-SCALE BATTERY STORAGE – PROJECT INSIGHTS

About this survey

The purpose of this survey is to gather information on key lessons learned and identify knowledge gaps that could be addressed by future projects. Your responses will be collected and analysed as a group, with all other respondents from this survey. Aurecon will use this information to prepare a project insights report to enable projects under development now to incorporate those lessons and improve the commerciality of the sector as a whole. Participants will be provided with a copy of the draft report to review prior to publication to enable review for accuracy and ensure no confidential information is published.

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Project Overview

1. Which LSBS project are you involved in?

- ☐ ESCRI
- ☐ Ballarat
- ☐ Gannawarra
- ☐ Lake Bonney

2. What is your role in the project?____

3. What were the key planned outcomes for the LSBS system? (select all that apply)

- ☐ Proof of technical concept/solution e.g. battery integration to an existing site
- ☐ Support to the NEM e.g. relieve congestion
- ☐ Revenue generation e.g. FCAS or causer pays
- ☐ Other ____

a. Have these been achieved/realized?

- ☐ Yes
- ☐ No
- ☐ Partially

b. What has been the driver for this success/discrepancy?

4. What were the key risks identified during project development? (select all that apply)

- ☐ OH&S
- ☐ Technical issues
- ☐ Fire suppression solution
- ☐ Regulatory Compliance
- ☐ Schedule Delays
- ☐ Cost Increases
- ☐ Supply-chain issues
- ☐ Accuracy of financial modelling e.g. FCAS revenue projections
- ☐ Grid Connection
- ☐ Grid Modelling
- ☐ Subcontractor issues e.g. EPC contractor performance
- ☐ Access to specialists e.g. 3rd party consultants
- ☐ O&M
- ☐ Geographical & site considerations e.g. weather, access
- ☐ Development approvals & planning (incl. flora/fauna & cultural heritage)
- ☐ Stakeholders e.g. local community, landowners, overseas suppliers
- ☐ Internal processes
- ☐ Scope creep / extensions of time / contractual issues
- ☐ Other ______________________________

a. Please provide details of the top five identified risks and their mitigation

	RISK	MITIGATION
1		
2		
3		
4		
5		

5. Which risks occurred during the project and were any of these unforeseen?

6. What implications might these have for either your future projects or the battery sector more generally?

Operational Strategy

7. What are the key functions/services delivered by the LSBS system on this project?

- [ ] FFR
- [ ] Contingency FCAS
- [ ] Regulation FCAS
- [ ] Energy Arbitrage
- [ ] Islanding
- [ ] Constraint Management

a. Please describe any innovations in your functions/services for this project

b. Please describe how the operating strategy manages operation of the LSBS system across the range of services provided

8. What are the functions/services that the LSBS system is capable of?

- ☐ FFR
- ☐ 'Simulated' Inertia
- ☐ Contingency FCAS
- ☐ Primary Frequency Control
- ☐ Regulation FCAS
- ☐ Energy Arbitrage
- ☐ Islanding
- ☐ Constraint Management
- ☐ System restart
- ☐ System strength as a service
- ☐ Power quality improvement
- ☐ Voltage control
- ☐ Other ______________________________

a. Where there are services that the LSBS system is capable of, but not providing for this project, can you explain why the function is not applicable or not being utilised on the project?

9. What is the bidding/market participation approach/system?

a. Please describe any innovations (current or planned) in your system

b. What were/are the challenges in developing the system?

c. Did your market participant IT systems have to be developed specifically for this project?

10. What are the key learnings from the LSBS system operation to date?

Business Case

11. What are the key revenue streams for the project?

- ☐ Contingency FCAS
- ☐ Regulation FCAS
- ☐ Energy Arbitrage
- ☐ Network Support Payments ______________________________ (please elaborate)
- ☐ Other ______________________________

12. What is the bankability of these revenue streams?

13. What is the relative proportion of the total revenue of each of these revenue streams?

____

14. How did the actual Capex spending compare to the projected budget (e.g. percentage over/underspend)?

a. What were the key reasons for any discrepancy?

15. How are the O&M costs comparing to the projected expenditure (e.g. percentage over/underspend)?

a. What were the key reasons for any discrepancy?

16. What were the key challenges in building a commercial business case? E.g. sourcing verifiable technical information, projecting revenue accurately, identifying funding sources, risk profile of the project and its perception by stakeholders, lack of industry knowledge or other.

a. Are these challenges changing as more projects come online?

Project Delivery

17. What was the contracting structure for the project (regarding ownership, operation, LSBS system delivery, O&M etc.)?

18. What were the key challenges and lessons learnt regarding the contracting structure?

19. Reflecting on the final contracting structure, are there any opportunities to consolidate the number of parties involved, or reduce the complexity of the contracting model?

20. Please describe your experience of the grid connection and GPS process, especially as it relates to delivering a battery project?

    a. Was this experience in line with your expectations prior to commencing the project?

21. What is the O&M strategy for the project?

    a. What is the degradation/capacity maintenance strategy?

    b. Have you identified any key O&M lessons?

Regulation

22. What are the key areas of regulatory reform relevant to your battery project and how would this impact projects similar to yours in the future?

Thank you for participating... Two final questions:

1. If you were to repeat the project, what (if anything) would you do differently?

2. What new opportunities can you identify for innovation in future large-scale battery projects?

As part of the analysis of this survey, we may wish to clarify some of your answers. Would you be happy for us to contact you via email or phone with any further questions we may have?

☐ Yes

☐ No

Further information is available at
arena.gov.au

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