ESCRI-SA Battery Energy Storage

Final Knowledge Sharing Report

March 2021

In partnership with:

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The purpose of this document is to provide a summary of the ESCRI-SA Battery Energy Storage Project from commencement to two years following initiation of commercial operation.

This activity received funding from ARENA as part of its Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

ARENA
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Australian Renewable Energy Agency

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Glossary of Terms

Term	Description
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
BOA	Battery Operating Agreement
CPP	Consolidated Power Projects Australia Pty Ltd
EPC	Engineering, Procurement, and Construction
ESCOSA	Essential Services Commission of South Australia
ESCRI-SA	Energy Storage for Commercial Renewable Integration, South Australia
ESD	Energy Storage Device
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
GPS	Generator Performance Standards
Hz	Hertz
Hz/s	Hertz per second
IDS	Island Detection Scheme
ITR	Inspection Test Report
kV	Kilovolts
MGC	Micro Grid Controller
MVP	Minimum Viable Product
MW	Megawatts
MWh	Megawatt hours
MWs	Megawatt seconds
NEM	National Electricity Market
NER	National Electricity Rules
Project	ESCRI-SA Phase 2
PSSE	Power System Simulator for Engineering
RoCoF	Rate of change of frequency
SA	South Australia
SCADA	Supervisory Control and Data Acquisition
SIPS	System Integrity Protection Scheme
SOC	State of Charge
SRMTMP	Safety, Reliability, Maintenance and Technical Management Plan
WPWF	Wattle Point Wind Farm

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Executive Summary

Energy Storage for Commercial Renewable Integration, South Australia (ESCRI-SA) is a 30 MW, 8 MWh Battery Energy Storage System (BESS) at Dalrymple on the Yorke Peninsula of South Australia.

The Dalrymple ESCRI-SA BESS has been used as a vehicle of headline innovation leadership across a broad range of services that has included:

- development of a first-of-its-kind commercial model to support the provision of regulated reliability and security services by a Network Service Provider (ElectraNet) alongside competitive market services (AGL), challenging perceived limitations to network ownership of battery energy storage technologies
- navigating the market registration, licensing and connection processes for the first time, paving the way for others to follow – a very transparent approach assisted AEMO in developing registration procedures for utility-scale battery technology
- largest autonomous regional micro-grid development to date, co-optimised for both grid-connected and islanded operation with 100% renewables, allowing seamless transition between the two operating modes (for both planned and unplanned islanding)

The project was part funded by the Australian Renewable Energy Agency (ARENA) with the aim to deliver several key outcomes for the electricity industry. All these outcomes have been achieved, as summarised in the following table.

Outcome	Comment
Demonstrate the deployment and operation of a large-scale BESS to deliver a combination of network and market benefits	The BESS entered commercial operation on 14 December 2018 providing both network and market services
Demonstrate a contracting and ownership model to maximise the value of a BESS	The contracting and ownership model facilitated the integration of the Wattle Point wind farm to allow AGL a much wider use of the BESS MWh capacity between 10% – 90%
Test the regulatory treatment for the ownership of large-scale BESS by regulated transmission network service providers	The AER accepted ElectraNet's proposed regulatory treatment of the BESS at Dalrymple
Provide price discovery for the deployment of a large-scale grid connected BESS	Price discovery was provided for capital expenditure Operational performance and market revenues were documented in four Operational Reports
Highlight and address technical and regulatory barriers in the deployment of large-scale batteries	Technical and regulatory barriers were navigated with regulatory treatment accepted and the BESS registered by AEMO

Table 1: Summary of key outcomes achieved

ElectraNet delivered an extensive knowledge sharing program to share information about BESS performance, as part of its funding agreement with ARENA. The extent of knowledge sharing represents unprecedented transparency for a grid-scale BESS in the National Electricity Market (NEM). This final project knowledge sharing report summarises the project outcomes and knowledge sharing material developed.

1. Introduction

Energy Storage for Commercial Renewable Integration, South Australia (ESCRI-SA) is a 30 MW, 8 MWh Battery Energy Storage System (BESS) at Dalrymple on the Yorke Peninsula of South Australia.

The ESCRI-SA project began as a concept in 2013 to explore the role of energy storage in a future with more variable renewable energy-based generation within Australia's larger interconnected energy system. This concept evolved into a consortium consisting of ElectraNet, AGL and Worley (the Consortium[1]), that jointly explored:

- the business case for such an energy storage device (Phase 1) - completed in 2015, this involved preliminary business case work
- the installation of a BESS (Phase 2) - completed in 2018, this involved procurement, installation, and commissioning of the BESS, and
- knowledge sharing in relation to operational performance (Phase 3) – this involved provision of operational performance information, technical and commercial in nature, for the first two years of commercial operation.

During the knowledge sharing period two major Project reports were published. In May 2018 "The Journey to Financial Close" was published, followed in October 2018 by "From Financial Close to Commissioning".

Four public reports have been published in relation to operational performance. These, respectively, have reported on the operational performance of the project for the successive six-month periods between 14 December 2018 and 14 December 2020.

This document is the final knowledge sharing report. It provides a summary of the development process for ESCRI-SA, the operational performance in the initial years of operation, the influence of the project on development of utility-scale batteries in the NEM and a broad view of lessons learned.

[1] The parties and their roles are described in Section 8

2. Project Background, Overview and Timeline

2.1 Phase 1 - Feasibility

Phase 1 was exploratory in nature and examined the role of a non-hydro Energy Storage Device (ESD) within the South Australian transmission system specifically designed to leverage value from the energy market and through both ancillary and network services. A key objective of the work was to demonstrate that such storage adds value to renewable energy integration, with the ESD targeting that outcome as well as additional services to improve its business case.

The work began with a simple assumption that energy storage could provide a range of functions of value in systems with higher variable renewable energy input, including energy arbitrage and other market-facing services such as ancillary services, but also network-related services such as voltage control and, potentially, deferral of network augmentation.

Phase 1 was agnostic on the ESD technology, in part to allow very broad thinking to evolve and different solutions to be compared, but also as the likely Phase 2 Project was expected to have poor economics and, therefore, be limited in size. However, pumped hydro was not considered as previous work in South Australia had suggested a much larger-scale asset would be required for this than the scale of project envisaged.

In Phase 1 it was intended that a multi-functional asset would be pursued, that is, one which leveraged both market and regulated revenue. At this time Australia had little experience with non-hydro energy storage within its interconnected systems and, internationally, the technologies involved were just emerging into the mainstream. This meant that the work had to concentrate on a range of issues across a broad spectrum of regulatory, commercial, contractual, technological, and siting issues.

All options considered were NPV-negative and the least-negative option, i.e., a 10 MW, 20 MWh ESD sited at the Dalrymple substation on the Yorke Peninsula, was chosen as the basis for the detailed business case. Significant local renewable energy generation (Wattle Point Wind Farm - WPWF) is connected at this site and appeared to have the most suitable characteristics to leverage value from such ESD sizing. A Lithium-Ion battery was used as the basis of the business case as this showed the best overall metrics.

Phase 1 of the ESCRI-SA Project was initiated through a funding agreement between ARENA and AGL that was signed in August 2014. It resulted in delivery of a final public report in December 2015 as the major Project deliverable. This final Phase 1 report can be found at the following link:

https://arena.gov.au/assets/2016/04/ESCRI-General-Project-Report-Phase-1.pdf

2.2 Phase 2 – Design, Construct and Commission

In ESCRI-SA Phase 2 (the Project) the Energy Storage Device (ESD) was renamed Battery Energy Storage System (BESS) in recognition that Lithium–Ion battery technology had been selected and was likely the long-term best solution.

The primary objective of the ESCRI-SA Phase 2 Project was to demonstrate that utility-scale energy storage can be a key enabler of large scale intermittent renewable energy on an interconnected power system.

While the Project ultimately evolved to align more with the services needed within the South Australian power system, the basic concepts of siting at Dalrymple and BESS technology remained and became the backbone of the final solution.

The issues in South Australia around system security changed the Project direction to consider different services, particularly fast frequency response services that were emerging as valuable. This provided a different flavour to the asset, from one focused more on the energy market, to one focused more on system security. Several iterations ensued with vendors around price, modelling of monetisable revenues, and the aim of limiting ARENA contributions to the final asset while maximising demonstration value.

Ratings finally selected involved an increase in the power (MW) capability of the asset, and a decrease in its energy storage depth (MWh), with a nominal 30 MW/ 8 MWh (at end of term) device finally selected. Through this process the revenue items of the Project changed in terms of services provided, their respective contributions, and the interaction between the parties involved, particularly commercially. The Project lifetime also consolidated to twelve years.

The ESCRI-SA BESS business case depended on three funding sources/ revenue:

- Regulated benefits that underpin a regulated investment
- Unregulated revenue
- ARENA grant funding

The final ESCRI-SA Phase 2 case was presented to ARENA in early 2017 and a final Agreement was signed in August 2017.

This Agreement included several Milestones, the first of which involved the Project proceeding to Financial Close, with a target date of 30 October 2017 and key deliverables regarding financial modelling, approvals/ authorisations, Engineering, Procurement and Construction (EPC), and Operations and Maintenance contracts/ agreements, insurance, and risk management.

The Project concluded on completion of commissioning of the BESS, with all EPC works completed other than integrated operation of the BESS and WPWF under islanded condition.

The overall commercial arrangements for the Project are summarised in the following diagram.

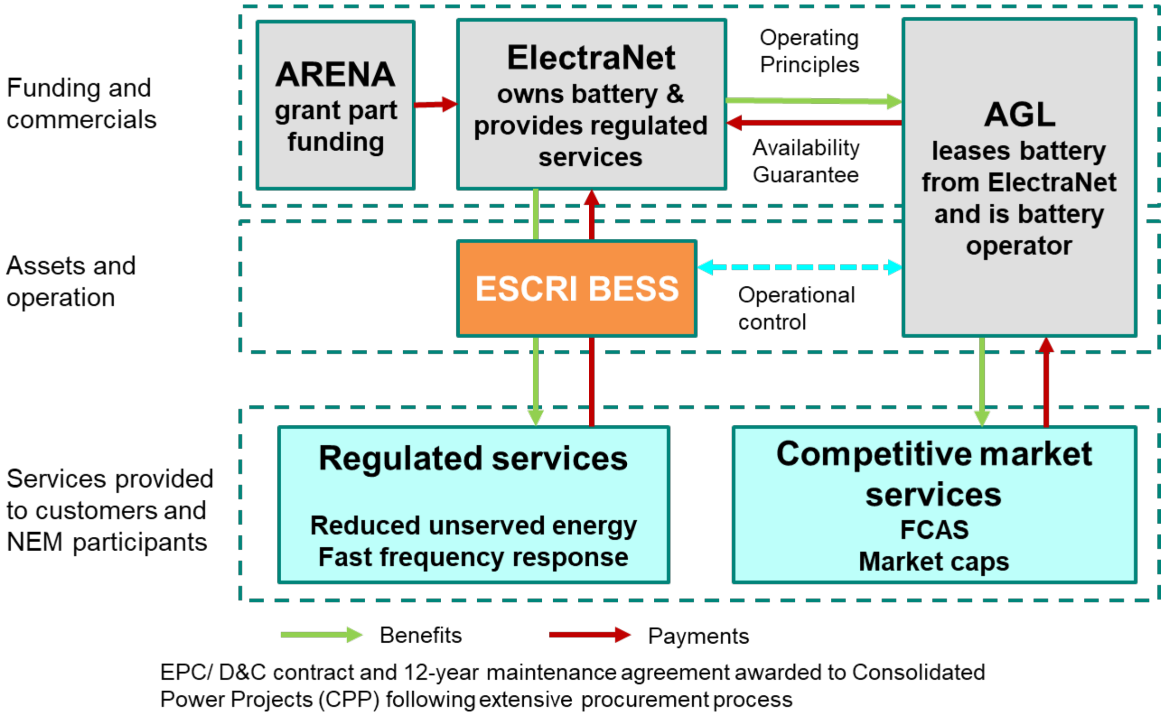

Figure 1: Overall commercial arrangements for the Project

A secondary objective for the Project was to allow evaluation of a local islanded system where demand is supplied by a local wind farm with no conventional generation and regulation services are provided by the BESS. It was expected that this would provide information about what is required for broader operation of the South Australian power system with 100% intermittent renewable generation, such as the amount of storage that is needed to manage varying levels of demand and intermittent generation.

The ESCRI-SA BESS is connected to ElectraNet's Dalrymple two 25 MVA 132/33 kV transformer substation, seven kilometres south-west of Stansbury on the lower Yorke Peninsula in South Australia, about 200 km from Adelaide. The Dalrymple substation is radially supplied via Hummocks and Ardrossan West substations and has an average demand of about 3 MW. Installation of the BESS has provided the ability to supply the local Dalrymple demand in island mode with WPWF as part of that island.

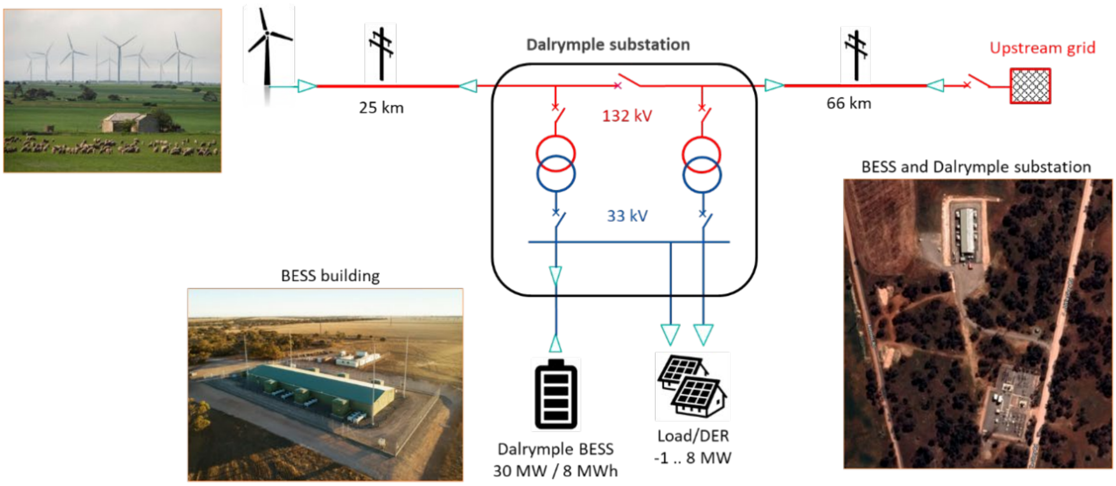

Figure 2: Simplified single line diagram of Dalrymple BESS connection

Figure 3: Aerial photograph of Dalrymple BESS and the Dalrymple substation looking south

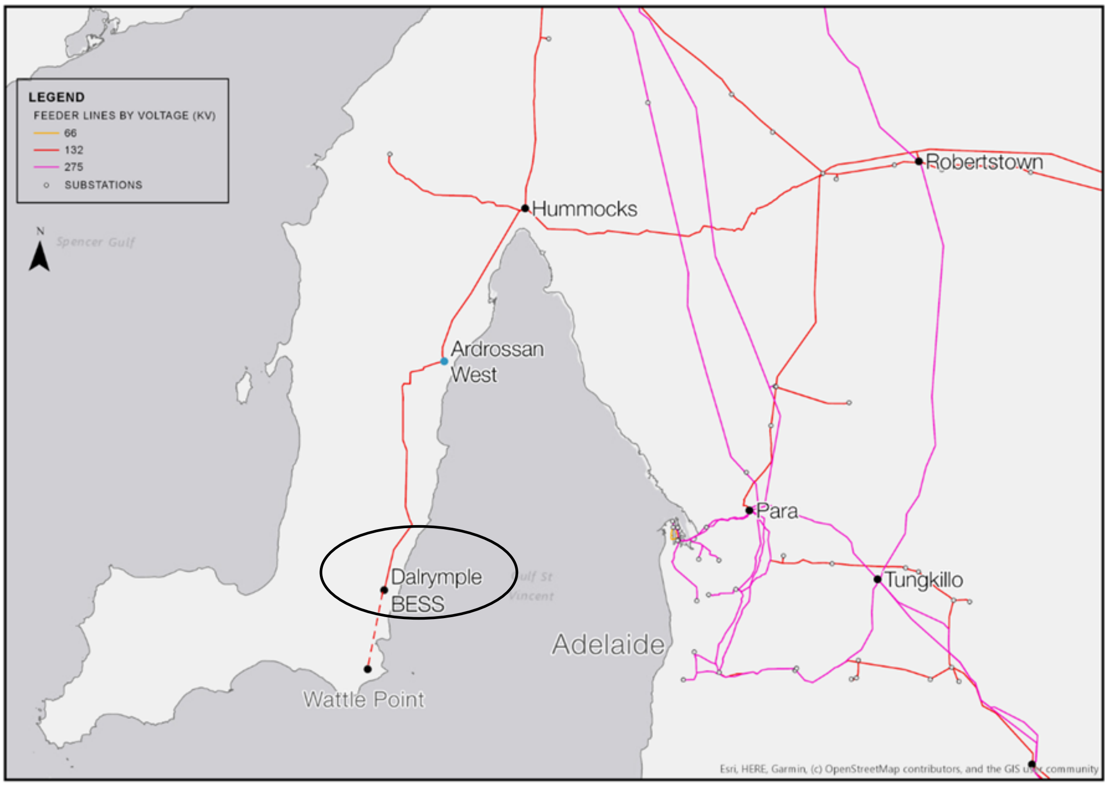

Figure 4: Dalrymple connection point on the South Australian transmission system

2.3 Phase 3 – Commercial Operation

The purpose of Phase 3 has been to share knowledge in relation to operational performance of the ESCRI-SA Project. This has involved provision of operational performance information, technical and commercial in nature, for the first two years of commercial operation. Documentation has been posted to the ESCRI-SA data portal, available at www.escri-sa.com.au. Further information is included in Section 3 of this report.

During Phase 3 a total of four operational reports have been published. These have focused on the four successive six-month periods of the first two years of commercial operation of the ESCRI-SA Project.

2.4 Project outcomes

The key project outcomes, as defined in the Funding Agreement, included:

- Demonstrate the deployment and operation of a large-scale BESS to deliver a combination of network and market benefits
- Demonstrate a contracting and ownership model to maximise the value of a BESS
- Test the regulatory treatment for the ownership of large-scale BESS by regulated transmission network service providers
- Provide price discovery for the deployment of a large-scale grid-connected BESS, and
- Highlight and address technical and regulatory barriers in the deployment of large-scale batteries

Specific services and capability required of the ESCRI-SA BESS included:

- Supply of Fast Frequency Response (FFR) ancillary services into South Australia to reduce constraints on the Heywood interconnector, resulting in increased flows on the interconnector
- Reduction of expected unserved energy to Dalrymple following loss of supply, involving islanding of the BESS with the local load, the Wattle Point Wind Farm at reduced output, and local rooftop PV to supply local load until grid restoration
- Market trading of electricity within the South Australian National Electricity Market (NEM) region and provision of Frequency Control Ancillary Services (FCAS) services

It is pleasing to note that all the project outcomes, services and capability listed above have been achieved or successfully demonstrated in ESCRI-SA BESS.

Since commencement of the Project, the BESS has also been incorporated into the System Integration Protection Scheme (SIPS) to support the existing Heywood interconnector by injecting real power into the system following a system event that causes substantial loss of generation in South Australia.

2.5 Key Milestones

Key milestones of the project are listed in Table 2. A more comprehensive list of milestones and deliverables is available in Appendix 1.

Milestone	Date
ARENA Conditional Funding Approval	13 April 2017
ARENA Funding Agreement Executed	15 Aug 2017
EPC contract and Maintenance Service Agreement executed	21 September 2017
Battery Operating Agreement executed	21 September 2017
Development Approval received	11 October 2017
Financial close	13 November 2017
Energisation of BESS	30 April 2018
Grid-connected commissioning completed	7 September 2018
Start of commercial operation	14 December 2018
Islanding with the Wattle Point Wind Farm commissioning completed	5 April 2019
Energy Networks Australia: 2019 Industry Innovation Award	12 September 2019
South Australia Premier's Award: 2019 Energy Sector - Transformational Innovation	15 November 2019
Two-year knowledge sharing period end	14 December 2020

Table 2: Key project milestones

3. Performance of ESCRI-SA

The ESCRI-SA BESS has now operated for two years in the NEM. During this time, it has successfully demonstrated both regulated and market services under a network ownership model. It has operated in islanded mode to improve local supply reliability and provides FFR to increase the Heywood interconnector capacity.

3.1 How ESCRI-SA has been used

The BESS was designed and commissioned to provide the following services, in order of priority:

1. Islanded operation to enhance local reliability of supply
2. Fast Frequency Response (FFR)
3. Network support
4. Frequency Control Ancillary Services (FCAS)
5. Energy arbitrage (previously referred to as Cap trading)

AGL operates the BESS and trades in the FCAS and Energy markets. During a network event where the BESS is required to respond, it has been configured to automatically switch to one of the higher priority services.

During commercial operation, AGL is required to operate the BESS between 10% and 90% of the installed battery capacity. This is to ensure that the BESS always has the capacity to respond to a network event.

From the outset, more revenue was expected from FCAS than arbitrage, and this has proven to be the case.

ESCRI-SA has been used as a vehicle of headline innovation leadership across a broad range of services that has included:

- development of a first-of-its-kind commercial model to support the provision of regulated reliability and security services by a Network Service Provider (ElectraNet) alongside competitive market services (AGL), challenging perceived limitations to network ownership of battery energy storage technologies
- navigating the market registration, licensing and connection processes for the first time, paving the way for others to follow. A very transparent approach assisted AEMO in developing registration procedures for utility-scale battery technology
- largest autonomous regional micro-grid development to date, co-optimised for both grid-connected and islanded operation with 100% renewables, allowing seamless transition between the two operating modes (for both planned and unplanned islanding)

ESCRI-SA also provides pre-emptive emergency response as part of the SA System Integrity Protection Scheme, providing fast power injection into the network following a significant loss of generation to help prevent a major loss of supply to customers.

Where regulated services are needed, ESCRI-SA supports this well at the extremity of a system where support is needed.

A key benefit for ESCRI-SA is reduction in unserved energy, through islanding. However, as successful as this has been, a key focus for future batteries will more likely be fast frequency response and voltage control.

AEMO processes were not fully suitable when ESCRI-SA was seeking approval, but they have improved, and refinement is ongoing. As the connection process has become more complex, through consideration of issues such as system strength, etc., but not specifically due to batteries, this battery and others have improved AEMO's processes. Much greater analysis is required now prior to connection, and a lot of resources (human and computer) are consumed to meet the requirements.

3.2 Technical performance and impact

In the two-year reporting period from 14 December 2018 when the BESS entered commercial operation, until 14 December 2020, the BESS experienced a total of twenty-nine operational system events. Most of these events were single-line trips with the remaining being either frequency events or led to the BESS supplying load to prevent or reduce the duration of an unserved energy event.

High speed data recorded at Dalrymple substation has been downloaded by ElectraNet and plotted for each transmission network fault. This data demonstrates that the BESS successfully rode through the network fault events and its voltage, active power and reactive power response are in line with its design and technical performance expectations.

The BESS responds almost instantly to the system voltage dip during respective faults and injects a significant amount of active and reactive power into the network to support network voltage recovery and prevent or reduce the duration of an unserved energy event.

The following are several examples of how the BESS has responded positively to system events:

1. On 20 December 2019 at 13:52, the Ardrossan West - Dalrymple 132kV line tripped and successfully reclosed following a single phase to ground fault caused by lightning. The Dalrymple local supply remained connected and supplied by the Dalrymple BESS until re-synchronisation at 13:55. The Wattle Point Wind Farm was generating 15 MW when the fault occurred and remained connected. The BESS output for the unplanned outage event is illustrated in the graph below. The negative numbers denote generation of power. This event demonstrated the BESS' ability to successfully support this islanded portion of the network during the event, and thus enhance local reliability of supply and reduced the extent of unserved energy.

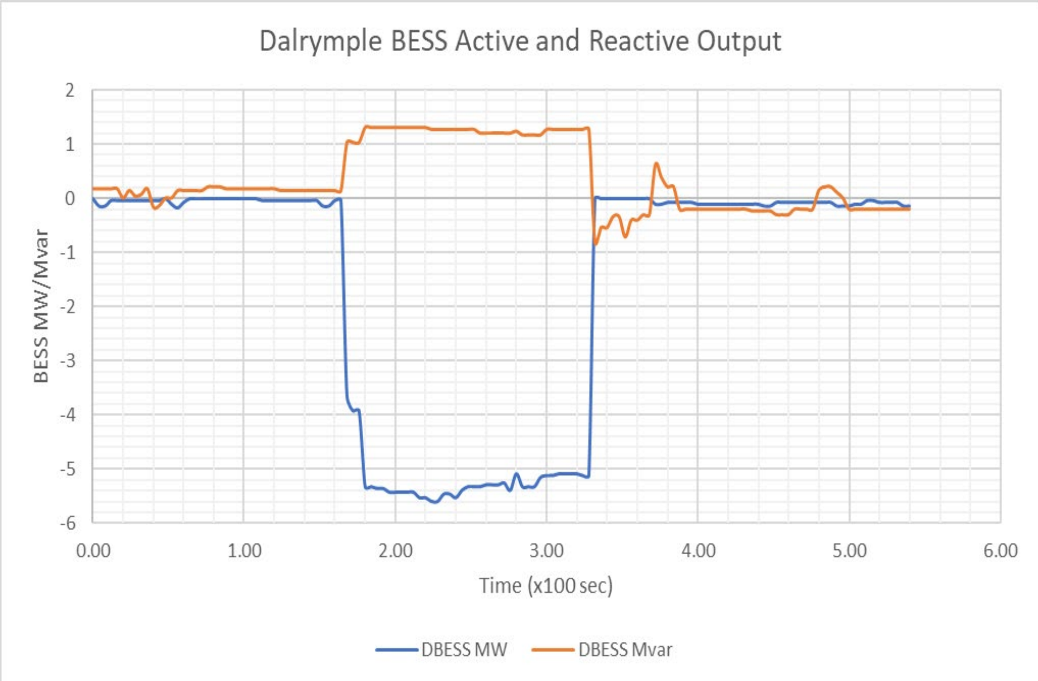

Figure 5: Dalrymple BESS active and reactive power output during the event

2. On the 13th January 2020 at 2:19:32, catastrophic failure of S phase CT 7022 at Waterloo resulted in operation of the Waterloo South Bus Zone protection and CB7022 CB Fail protection. This resulted in tripping of Waterloo TF5, Waterloo South Bus, Waterloo-Hummocks line and Hummocks TF1 (CB failed). Dalrymple BESS response due to this fault are shown below.

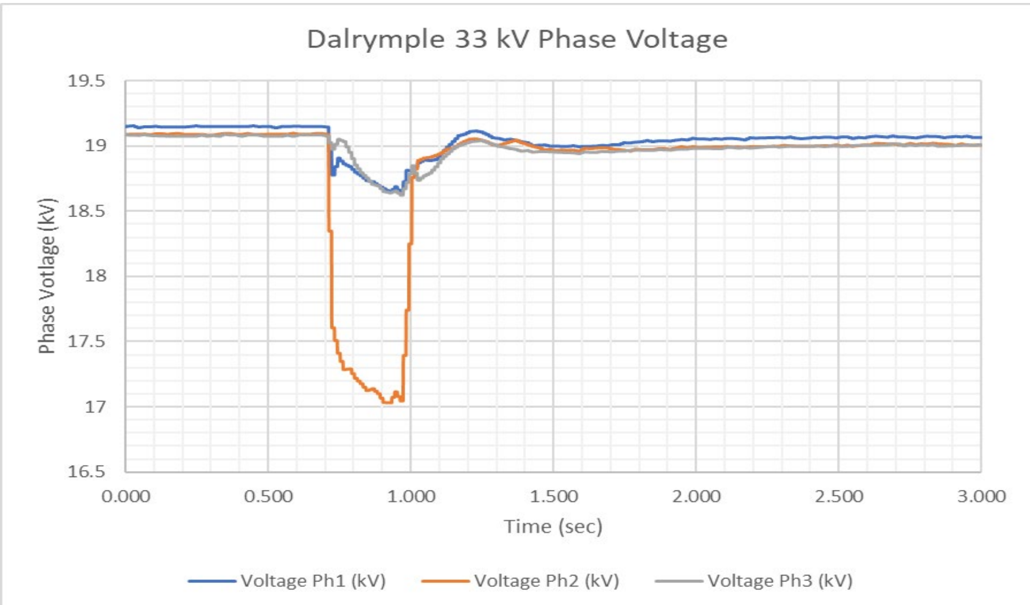

Figure 6: BESS voltage measured at the Dalrymple 33 kV substation

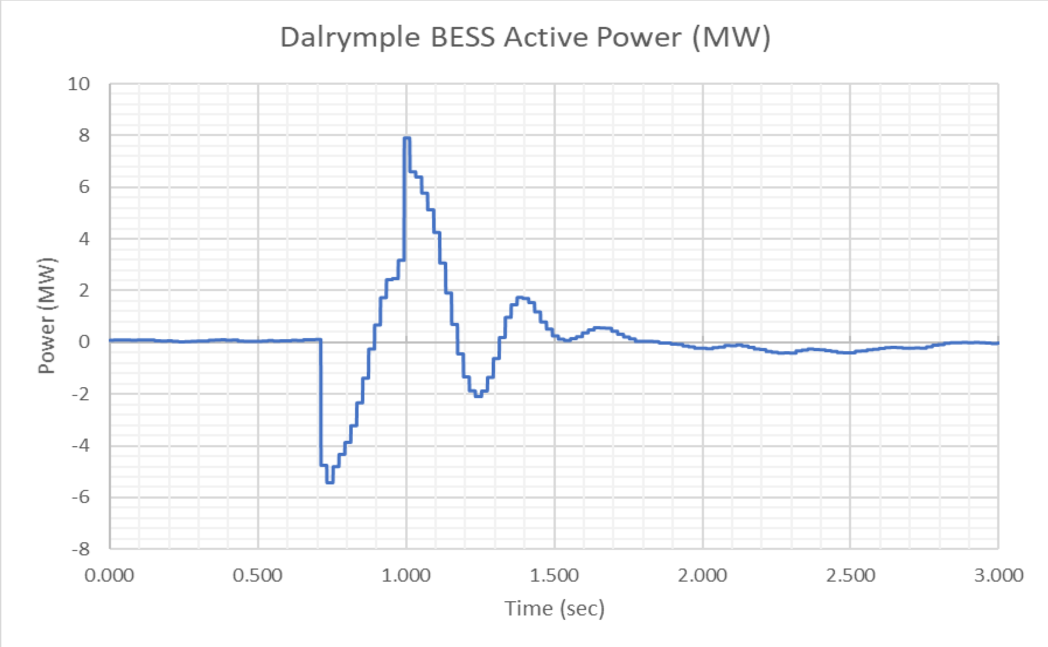

Figure 7: BESS active power output measured at the Dalrymple 33 kV substation

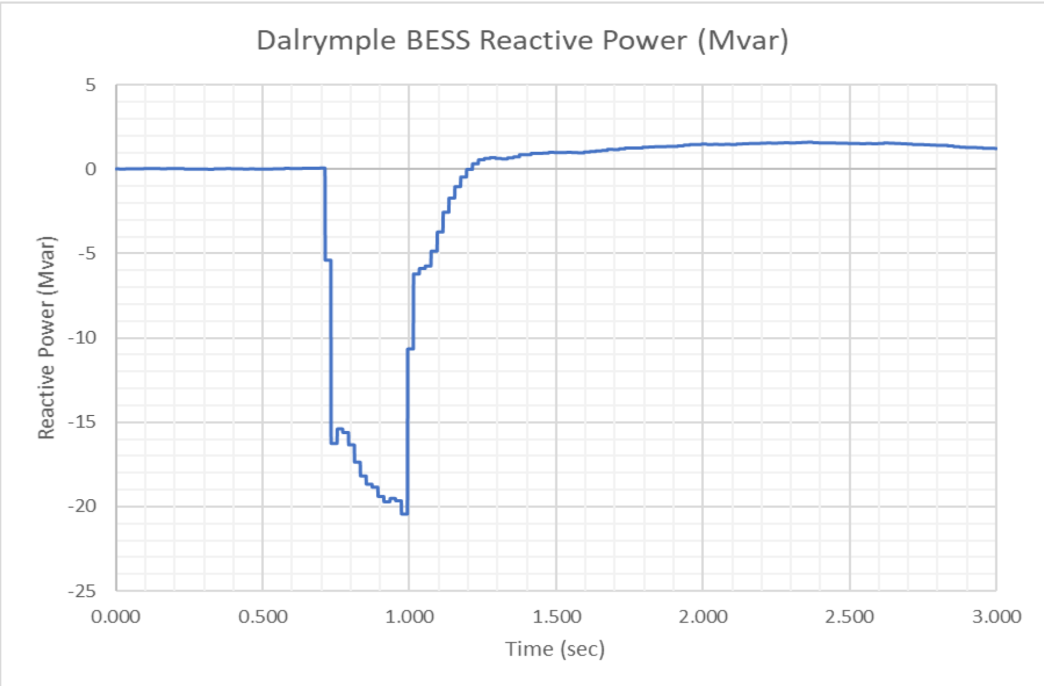

Figure 8: BESS reactive power output measured at the Dalrymple 33 kV substation

During this event the voltage of Phase 2 instantly dipped 11% before recovering after 0.3 seconds and oscillating slightly before becoming steady. The BESS responded immediately to initially consume power, then export it, as it supported the network to recover and more quickly reach steady state during the 2.5 seconds following the fault. This event demonstrated the BESS' ability to provide fast frequency response (FFR) and network support.

3.3 Performance against original objectives

3.3.1 Overall financial performance

ARENA contributed $12m funding support through its Advancing Renewables Programme. The funding agreements between ARENA, ElectraNet and AGL include a provision for ARENA to recoup part of any upside return from the commercial operation of the BESS. It is pleasing to note that the funding provided by ARENA will be returned in full through the sharing of revenue generated by operation of ESCRI-SA in FCAS services and arbitrage markets.

3.3.2 Key metrics

Table 3 presents a summary of the key performance metrics of ESCRI-SA over the past two years.

	Value for 6-Monthly Reporting Period				2-year Total or Average
Key Performance Metric	**14-12-2018 to 14-06-2019**	**14-06-2019 to 14-12-2019**	**14-12-2019 to 14-06-2020**	**14-06-2019 to 14-12-2020**	**14-12-2018 to 14-12-2020**
Average BESS Availability	98.01%	97.35%	98.93%	98.80%	98.27%
Total Energy Consumed	1,370 MWh	2,006 MWh	1,499 MWh	1,316 MWh	6,191 MWh
Total Energy Exported	160 MWh	768 MWh	198 MWh	99 MWh	1,225 MWh
Average auxiliary load and losses (% of 30 MW rated capacity)	2.19%	2.25%	2.35%	2.19%	2.25%
Number of Charge and Discharge Cycles (per BOA definition)	2	4	1	1	8
BESS Charging Cost	$120,000	$101,000	$76,000	$32,750	$329,750
BESS Discharge Revenue	$116,000	$97,000	$102,000	$4,820	$319,820
FCAS Revenue	$1.33m	$3.73m	$15.6m	$1.94m	$22.6m

Table 3: Summary of the key performance metrics of ESCRI-SA over the past two years

The two market revenue streams for the BESS utilised throughout the first two years of commercial operation were energy arbitrage and provision of FCAS services to the market. In each of the four six-month periods most of the revenue earned from the BESS was through the provision of FCAS services.

The total revenue earned from energy arbitrage and FCAS services combined was much greater than expected when compared to respective periods in the business case, entirely driven by significantly higher FCAS revenue than expected.

Real-life data of standby costs, losses, etc. are now known from the ESCRI-SA experience, and this can be used to assist other projects. The average BESS availability for the two-year period was 98.27%, which is greater than the 96% Guaranteed Annual Availability required under the Battery Operating Agreement (BOA).

The energy consumed by the BESS is significantly higher than the energy exported to the grid. The comparatively high energy use is because the BESS is designed as a power battery, rather than an energy battery, and therefore needs to be available all the time to be able to respond to system events at any point in time. This results in higher auxiliary load losses from transformers, inverters, and the battery management system.

The number of charge and discharge cycles are contractually defined as the BESS state of charge (SOC) falling below 2.4 MWh. Limited cycles have been recorded during respective reporting periods, and this reflects how the BESS is being operated and how many significant unserved energy events have been avoided. Overall, for a power battery, the number of charge/discharge cycles is expected to be low, as this project has experienced.

3.3.3 Demonstration of Key BESS Regulated Services

Reducing Expected Unserved Energy/ Islanding

From 2006 to 2014 there was an average yearly loss of supply of 3.52 hours and 9.46 MWh for the Dalrymple connection point.

The benefits of being able to continue to supply the local load from the BESS island network during an outage are significant and go beyond reducing the duration of a loss of supply. For example, planned outages can be scheduled during normal hours rather than overnight and live line techniques need not be used, resulting in higher levels of safety for work crews.

Over the first two years of commercial operation there have been one planned outage and nine unplanned outages with five of these outages lasting longer than 5 minutes. The Dalrymple BESS has prevented or reduced the duration of the unserved energy events. In combination, these events reduced the cumulative loss of supply from approximately 11 hours down to about half an hour. Analysis of the load supplied during these islanding events indicates that the BESS has reduced the Unserved Energy by 24.3 MWh, which is more that the historical average of 18.9 MWh used in the original business case.

Fast Frequency Response (FFR) to reduce constraints on the Heywood Interconnector

Currently a 3 Hz/s rate of change of frequency (RoCoF) constraint is applied to the Heywood Interconnector. The constraint defines the maximum import/export limit allowed.

This is based on the amount of synchronous system inertia online in South Australia at any point in time.

To achieve 650 MW transfer across the Heywood Interconnector based on the 3 Hz/s RoCoF, approximately 5,400 MWs of inertia is required to be available in South Australia.

Detailed power system analysis and test results have demonstrated that the FFR from the ESCRI-SA BESS results in an increase in the Heywood Interconnector transfer capability which is equal to a total 200 MWs of equivalent inertia contribution from the BESS.

This 200 MWs ‘offset’ has been implemented in the RoCoF constraint equation. As a result, when the BESS is in service the total inertia requirement in SA for a 3 Hz/s RoCoF is reduced from 5,417 MWs to 5,217 MWs.

Since the BESS has been in commercial operation there has been two system frequency events due the loss of the South East – Heywood Interconnector. These were on 16 November 2019 and on 31 January 2020. These confirmed the actual operation of the FFR function of the BESS.

Over the first two years of commercial operation the RoCoF constraint was the binding constraint for Heywood Interconnector transfers for a cumulative total of 8.5 hours with the ESCRI-SA BESS in service. Without the BESS in service, it is estimated that the RoCoF constraint would have bound for 30.5 hours indicating a healthy improvement.

System Integrity Protection Scheme

Following the SA power system black event in September 2016, maintaining the connection of the Heywood Interconnector during a system event that results in significant generation loss in South Australia is a high priority.

The System Integration Protection Scheme (SIPS) was introduced to address this risk and is designed to rapidly identify conditions that could otherwise result in a loss of synchronism between South Australia and Victoria. The SIPS is designed to correct these conditions by rapidly injecting power from batteries or shedding sufficient load to assist in re-balancing supply and demand in South Australia and prevent a loss of the Heywood Interconnector.

The BESS has been incorporated into the SIPS and is able to provide rapid response on receipt of a SIPS command. The SIPS function of the BESS has been tested and operated correctly.

Over the first two years of commercial operation, there has been no system incident resulting in a significant amount of generation loss in SA to trigger the BESS response to the SIPS command.

3.3.4 Demonstration of Key BESS Market Services

The BESS has performed well over the first two years, generally autonomously. There has seldom been a need for AGL or ElectraNet to take operational action in response to a fault, meaning the battery has been highly available and well placed to perform its market services. To date, this has primarily been the provision of contingency FCAS.

Energy arbitrage

Throughout the 2-year period energy arbitrage provided less value than estimated in the business case. Revenue from energy arbitrage remained low in favour of maintaining optimal availability for contingency FCAS services.

FCAS

The main source of revenue for the two-year period was FCAS, providing $22.6 million compared to just $319,820 for energy discharge. This is consistent with the BESS operating as a power battery. The BESS market services are discussed in more detail in Section 5.

The majority of the BESS's current financial value is derived from trading in the FCAS markets. During this 2-year operational period, FCAS trading revenue was approximately $22.6 million. This was composed of contingency raise services and contingency lower services. To provide these contingency services, the BESS needs to be kept in a state where it can either charge (for lower services) or discharge (for raised services) in order to help return the frequency to the normal operating band following a credible contingency event.

Future Revenue Streams and Rebidding

While future revenue streams could include selling cap derivative products, AGL has not offered these products from the BESS to date.

AGL has developed an automated rebidding system which ensures timely and accurate information is sent to AEMO regarding the physical capabilities of the BESS.

The rebidding system was the Minimum Viable Product (MVP) required for National Electricity Rules (NER) compliance whilst trading in the NEM. The MVP software does not optimise energy arbitrage value (energy versus FCAS). AGL is currently developing an optimisation module to extract additional value from energy arbitrage. It is anticipated that this module will be commissioned and in-service prior to the commencement of five-minute settlement.

4. Knowledge Sharing

4.1 Knowledge Sharing Plan

The sharing of knowledge from ARENA funded projects is an integral component of any related Funding Agreement. The ESCRI-SA Knowledge Sharing Plan (KSP) defines the following:

- The key objectives of the Plan
- The sharing deliverables required to meet funding milestones
- The target audience for the sharing
- How confidentiality is maintained and how information is treated
- Specific high-value knowledge sought
- Data that must be generated, collected and stored
- Activities committed to as part of the Plan
- The role of certain parties and individuals involved with the Plan

Thirteen key Knowledge Sharing objectives are noted in the Plan. These are centred on:

- Demonstration of the equipment, services and role of transmission level batteries in the NEM
- Improved understanding of technical constraints and actual performance of battery assets in providing both market facing and regulated services
- Experience with, and improved understanding of, the elements which come together to deliver a utility-level battery storage asset
- Improved public awareness of battery assets

During Phase 2 and 3 of the Project the following knowledge sharing deliverables/ activities were performed:

Deliverable	KSP requirement	Actual
Establish Knowledge Sharing Reference Group, hold regular meetings	6	6
Technical Open Days (Site visit)	2	2
Web portal with knowledge sharing material, including operational data	1	1
Formal knowledge sharing reports and technical articles	7	10
Presentation at industry conferences	6	10
Direct engagement with other industry participants (national and international)	-	6
Transfer of portal information to ARENA	1	1

Table 4: Parameters available for historical data download

These deliverables are listed elsewhere in this report.

4.2 Knowledge Sharing Reference Group

Knowledge sharing activities have received specific focus during the ESCRI-SA Project, and this has continued for two years following commencement of commercial operation.

The role of the Knowledge Sharing Reference Group (KSRG) for the Project has been to operate as a forum for knowledge sharing related to the project. The KSRG was planned to "……be a forum where knowledge sharing material would be discussed, requests for particular tests or information considered and where the knowledge sharing pathway and approach would be confirmed" (ARENA Funding Agreement).

Term

The KSRG commenced at the initial meeting on 6 February 2018 and concluded at the last meeting on 16 September 2020. In general terms the KSRG first met prior to energisation of the BESS, the second meeting was held just after commercial operation commenced and the KSRG continued until 2 years after the asset reached commercial operation. Six formal meetings were held over its term.

Membership

ElectraNet appointed Advisian to assist as its Knowledge Sharing Partner, including as Chair of the KSRG.

The KSRG consisted of representatives from a broad range of groups and companies who are interested in the advancement of knowledge of transmission-level battery energy storage and renewable energy integration within the National Electricity Market (NEM).

Organisations that participated in the KSRG were:

Advisian	Federal Government
AEMC	Government of New South Wales
AEMO	Government of Queensland
AER	Government of South Australia
AGL	Government of Victoria
Australian Energy Council	Government of Western Australia
Australian Renewable Energy Agency	SA Power Networks
Clean Energy Finance Corporation	TasNetworks, representing Govt. of Tasmania
CSIRO	University of Adelaide
ElectraNet	University of South Australia
Energy Networks Australia	

Table 5: Organisations that participated in the KSRG

Workings of the KSRG

KSRG meetings provided invitees with an update on Project progress and a forum for discussion around knowledge and learnings produced. The KSRG provided feedback and guidance on Knowledge Sharing for the Project, including:

- Commentary on new learnings and potential areas of future focus
- Feedback on results or analysis undertaken by others on asset performance
- Indication of what issues are most relevant to broader stakeholders
- Suggestion of tests of the battery system that could be explored
- Feedback on overall Knowledge Sharing material

The KSRG was advisory in nature and was not an approval body for Knowledge Sharing material. Input from the KSRG helped ElectraNet and its partners meet the needs of a broad stakeholder base with interests in the future of large-scale batteries within the NEM. Members were not required to reach consensus on issues or make binding group decisions or submissions. Minutes of KSRG meetings are available to all enquirers via the portal.

Role of KSRG invitees

The principal role of KSRG invitees was to attend meetings and site visits and to engage in discussion around Knowledge Sharing for the Project. Matters and materials identified by ElectraNet or the Chair as commercial in confidence were not to be disclosed by invitees.

4.3 Portal

The ESCRI-SA web portal (www.escri-sa.com.au) was one of the primary knowledge sharing tools for the Project. It provided the public with access to key information, including a real-time dashboard that showed the performance of the battery, Wattle Point Wind Farm, Dalrymple substation, the incoming transmission line, and the Lower Yorke Peninsula network. Downloadable data sets were also available.

The portal contained the ability to ask questions of the project team. It also contained relevant information including:

- Access to live and historical data from the operational BESS
- Images of the Project construction and operation
- All publicly published Knowledge Sharing material, including key reports, operational updates and presentations
- Information from the ESCRI-SA Knowledge Sharing Reference Group, which has been formed to share information about the Project, to discuss issues relevant to large scale batteries in the NEM, and to inform key stakeholders

On opening the ESCRI-SA portal, the viewer was presented with a display of "live" operating data and parameters. For example, at 3:10pm on 16 November 2020 the display showed the following information:

Figure 9: Portal display of "live" operating data and parameters

The viewer could then move to a Data part of the website, where immediate data visualisation or historical data download was available, in 4-second and 5-minute average format.

The data visualisation allowed any two of 37 parameters of the battery and surrounding electricity network and ambient environmental conditions to be selected for chart-type display.

The following is an example chart:

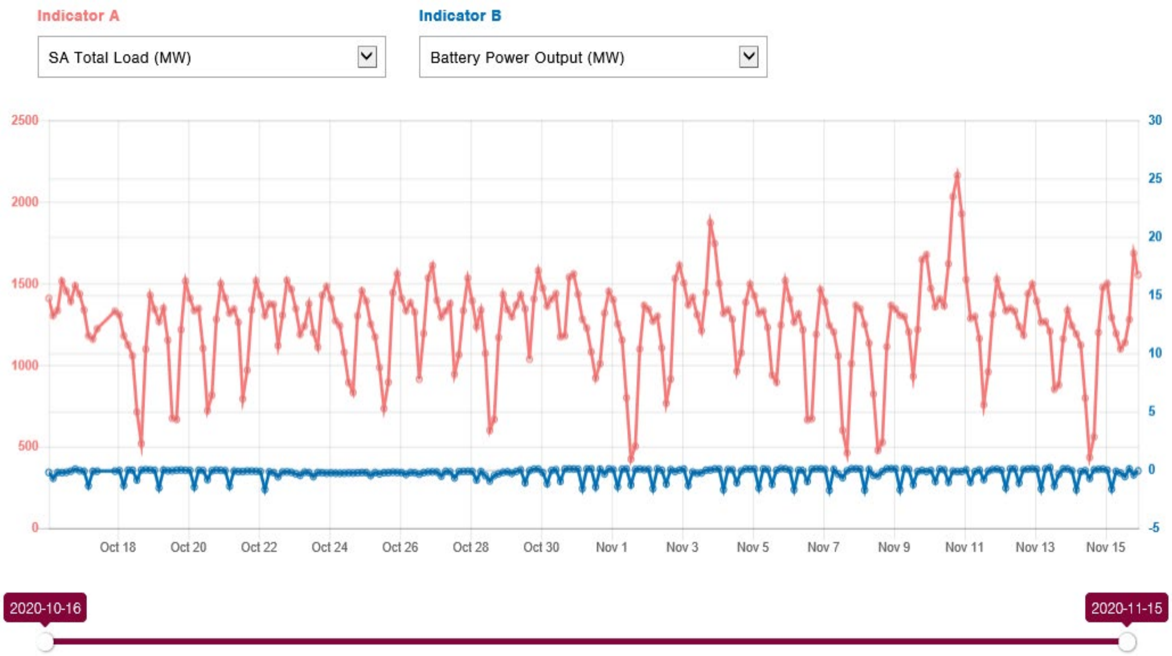

Figure 10: Chart-type display of parameters

Historical data downloads were also available. Any of the following parameters could be selected for download simultaneously.

Battery Indicator Group	
Battery Utilisation (%)	Battery Power Output (MW)
Battery Reactive Power (MVAr)	Battery Average Temperature
Battery Charge Level (AC)	Battery Energy Exported 24hr (MWh)
Battery Charge Level (MWh)	Battery Charge Level (%)
Battery Energy Imported 24hr (MWh)	Battery Polarity
Battery Max Output Capacity (MWh)	
Incoming Line indicator Group	
Incoming Line Real Power (MW)	System Frequency (Hz)
Incoming Line Utilisation (%)	
Lower Yorke Peninsula Customers Indicator Group	
LYP Customer Load (MVAr)	Dalrymple Solar Irradiance
LYP Customer Load (MW)	Dalrymple Outside Temperature
Load Provided by Windfarm and Battery (%)	

Substation Indicator Group	
Dalrymple Voltage	Dalrymple System Frequency
Dalrymple Substation Reactive Power (MVAr)	LYP Islanding Status
Dalrymple Substation Real Power (MW)	SA Total Load (MW)
Substation Details Indicator Group	
Operational status of each of 7 circuit breakers	Wattle Point Wind Farm CB Operational Status
Wattle Point Wind Farm Indicator Group	
Wattle Point Wind Farm Reactive Power (MVAr)	Wattle Point Wind Farm Real Power (MW)
Wattle Point Wind Farm Operating (%)	Dalrymple Wind Speed

Table 6: Parameters available for historical data download

Portal Usage

Between 14 December 2018 and 14 December 2020, Google Analytics shows that the site has been visited 3350 times from interested parties from 40 countries, with the number of views peaking in January, May and October of 2019, and May, July and October of 2020. Most portal views were through direct access to the website, rather than LinkedIn, Empired, Google or other sources or channels. Further details are shown in Figures 10 -12 below.

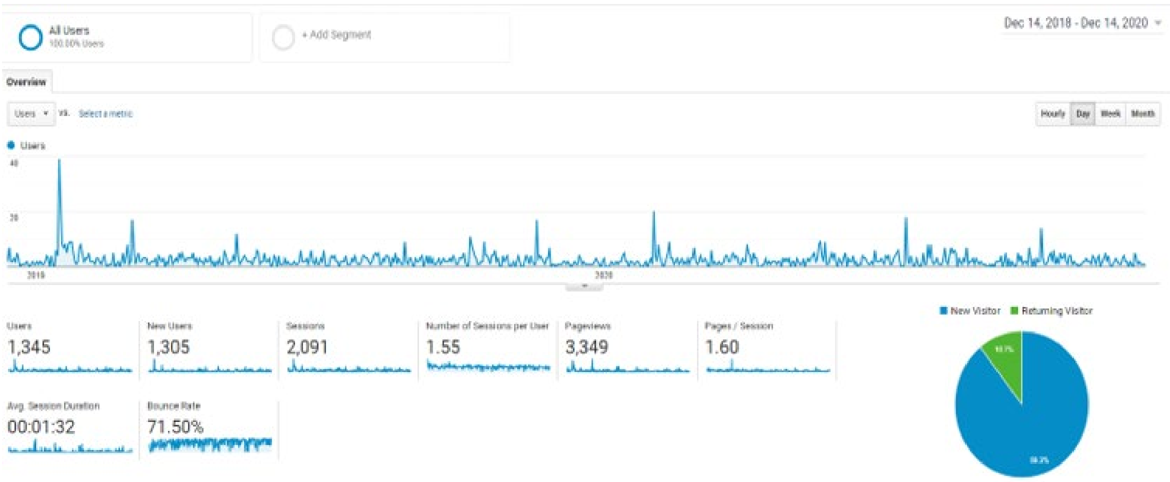

Figure 11: ESCRI-SA portal page views (24 months)

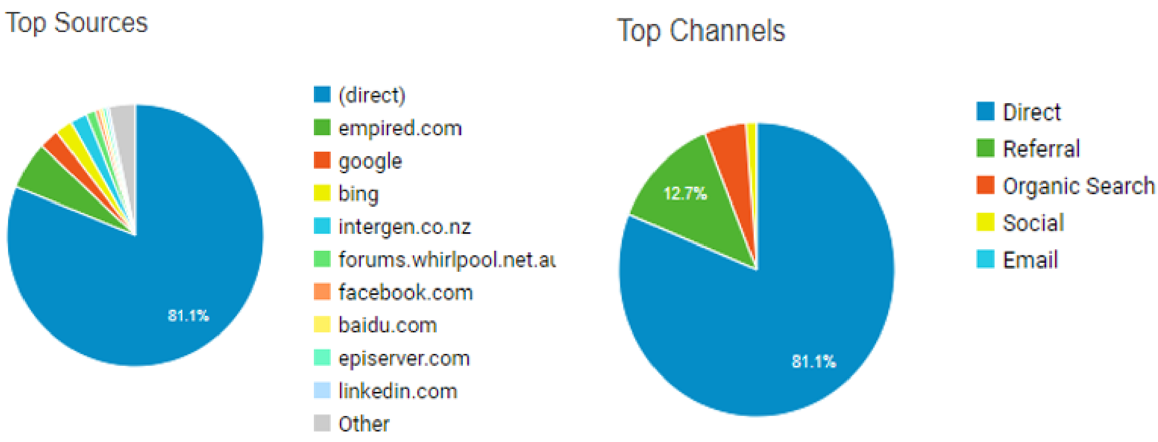

Figure 12: Top sources and channels used to locate ESCRI-SA portal (24 months)

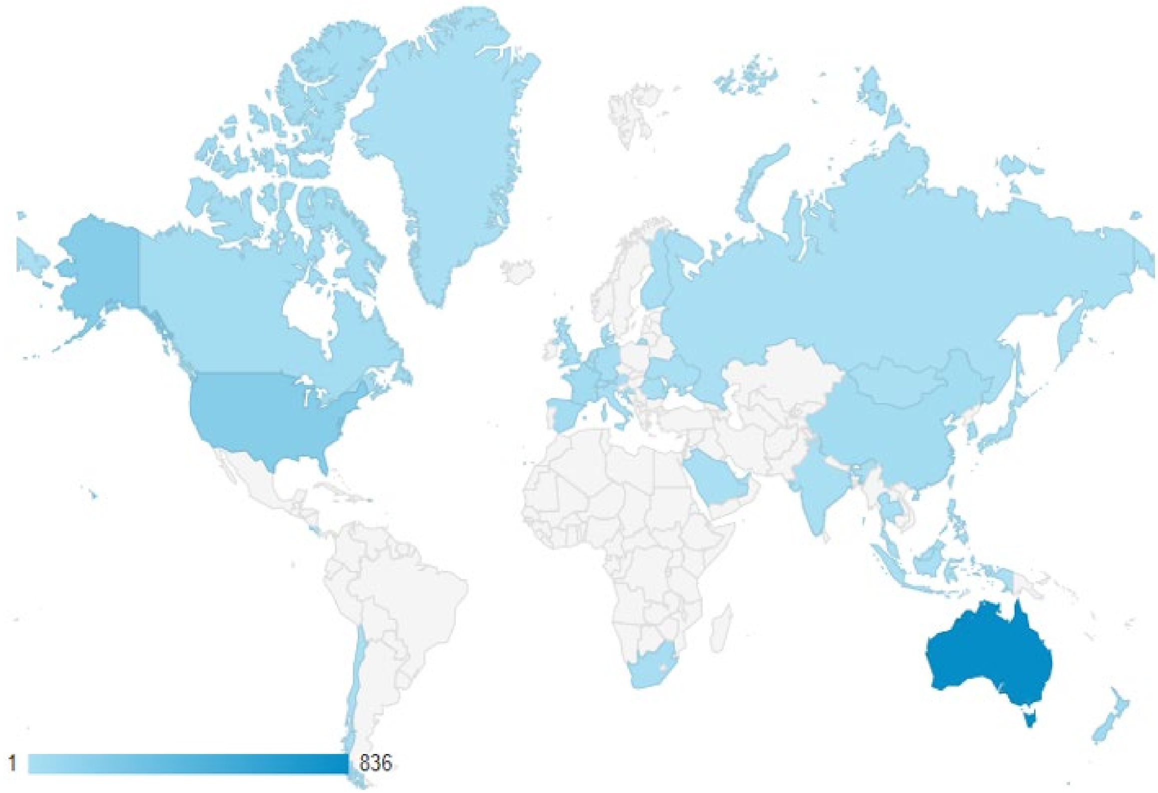

Figure 13: Geolocation of ESCRI-SA portal users (24 months)

4.4 Knowledge Sharing Material

Note that project reports, presentations, KSRG material and event data is available at https://www.electranet.com.au/electranets-battery-storage-project/ as well through the ARENA Knowledge Bank. The 5-minute data over the first two year of operation is also available from the ARENA Knowledge Bank.

5. Influence on Development of Batteries in the NEM

The following are some observations of personnel in the industry regarding the influence of the ESCRI-SA project:

ARENA

“The ESCRI-SA project has been a critical element of ARENA's large-scale battery portfolio in supporting the development of valuable industry knowledge of the technical capabilities of batteries, including the importance of inverters in supporting the grid. ESCRI has also demonstrated the potential (as well as the barriers) for large scale batteries to provide multiple market and grid services that can ultimately benefit the system and energy consumers.”

Rainer Korte - ElectraNet

“ElectraNet is very pleased to have delivered the innovative Dalrymple 30 MW, 8 MWh Battery Energy Storage System (BESS) with its project partners.

Energy storage has a significant role to play in the future energy system with the continued growth of intermittent renewable energy sources.

The Dalrymple BESS is the first transmission grid-connected battery in the NEM providing both regulated and competitive market services. The success of the project, which has been in full commercial operation since December 2018, required significant innovation leadership including:

- development of a first-of-its-kind commercial model to support the provision of regulated reliability and security services by a Network Service Provider (ElectraNet) alongside competitive market services (AGL), challenging perceived limitations to network ownership of battery energy storage technologies
- navigating the market registration, licencing, and connection processes for the first time paving the way for others to follow
- largest autonomous regional micro-grid development to date co-optimised for both grid-connected and islanded operation with 100% renewables allowing seamless transition between the two operating modes (for both planned and unplanned islanding)

The Dalrymple BESS project has also demonstrated further innovation leadership with the added function to provide pre-emptive emergency response as part of the South Australian System Integrity Protection Scheme (SIPS), providing fast power injection into the network following a significant loss of generation to help prevent a major loss of supply to customers.

The BESS not only supplies Fast Frequency Response to help balance the electricity network and reduce operating constraints on the Heywood interconnector, but also keeps the lights on in the Dalrymple service area during a loss of supply by working together with the existing 90MW Wattle Point Wind Farm and local rooftop solar PV systems in a seamless microgrid arrangement.

In this way the BESS supports the delivery of affordable, reliable, secure and sustainable energy to customers.

The Dalrymple BESS is the largest ‘edge-of-grid’ application that can seamlessly island the local distribution area (8 MW peak demand), which provides an ideal opportunity to learn how the reliability of ‘edge-of-grid’ communities can be improved.

The Dalrymple BESS project was supported by an extensive knowledge sharing program, with material available at https://www.electranet.com.au/electranets-battery-storage-project/ ”

Bruce Bennett - AGL

“By using a “grid forming” (voltage source) inverter to enable islanding of the Yorke Peninsula with the Wattle Point Wind Farm, the ESCRI-SA battery has triggered a lot of discussion on the benefits of such inverters at weak parts of the grid. The AEMC is now developing rules to insulate “grid forming” inverters from system strength charges that would otherwise be levied on plant connected to the grid.”

Barry O’Connell - AEMO

“Australia is leading the world with trialling new grid forming and advanced inverter technology, with the ESCRI-SA battery in South Australia the largest grid forming battery in the world. This technology has the potential to be an extremely effective tool in the power system toolbox, to support a low carbon grid and reduce our reliance on rotating synchronous machines. The ESCRI-SA project has given some very good insights into how such technology can be successfully applied. With the projections for the installed capacity of batteries in the NEM, there is a huge opportunity now to enable this functionality on these systems. It is an exciting time for this technology and the power industry, and this is one of the most exciting trials to demonstrate grid forming capability to both a local and an international audience.”

Paul Ebert - Worley

“When ESCRI was conceived as an idea the role of battery energy storage in the NEM was only a glimmer in the future, but it was obvious that a future with high penetration of variable renewables and distributed energy resources would need substantial transmission level storage capability to be both safe and stable. While it wasn’t ultimately the first large battery built in Australia, it was the first to marry market facing and regulated revenue services and push the value of islanding, and really has tested and proven a wide range of valuable service capability.

I think ESCRI has ultimately exceeded expectations around demonstration value which has included non-technical components which are critical to technology development and deployment, including fit with and appropriateness of regulation, the ability to win and hold social license, the contracting methodologies and standards that apply, the way plant is procured, how it is operated safely, and the ability to meet business case assumptions. All these risks, and the technical capability of batteries, are now better understood, and as a result it has been a wonderful contribution to the industry.

Worley/Advisian has been very proud to be part of the project.”

6. Key Learnings

6.1 Complexity and ambitious expectations

The complexity of developing an integrated grid and island BESS solution was underestimated in time, effort, and cost, resulting in setting very ambitious expectations for the Project. This included:

- Modelling and commissioning of the BESS system to meet NER requirements
- Expertise and experience of this type and application of a BESS in the NEM has resulted in multiple model revisions
- Deeper network changes on the planned island distribution network (local load)
- Integration with the Wattle Point Wind Farm was problematic due to its age and lack of models of the wind farm.

6.2 Technical barriers to deployment

The key technical challenges included ensuring that the Project meets Generator Performance Standards as part of the connection process, and the implementation of islanding capability with the battery supporting wind and solar generation in meeting local demand when islanded.

6.3 Regulatory barriers to deployment

Given the innovative nature of this demonstration Project, ElectraNet engaged early with regulatory bodies to determine an appropriate regulatory treatment. This engagement was quite substantial, and ultimately led to the AER and ESCOSA accepting ElectraNet's proposed regulatory treatment of the BESS under the National Electricity Rules and South Australian Electricity Transmission Code respectively.

However, in accepting the proposed regulatory treatment, the AER did not consider this should necessarily set a precedent for all future projects. More generally, several regulatory treatment issues remain to be resolved for other battery projects.

6.4 Acceptance of Modelling

Most of the delay in the Project resulted from difficulties with acceptance of the generator models. Specific lessons learnt include:

- It is crucial for the Original Equipment Manufacturer (OEM) to have a working understanding of the regulatory requirements (i.e. Chapter 5 of the NER) and any jurisdictional requirements (e.g. ESCOSA license conditions in SA).
- Models are repetitive in nature, and it is likely that models will pass compliance testing faster if the company has demonstrated experience in the NEM and AEMO is familiar with the generator configuration.

6.5 Safety and Islanding Detection

Network analysis and investigation of fault current requirements should be undertaken early in the Project, including where islanding is envisaged. This is to address issues, among others, that include:

- The inability of the BESS to provide enough fault current to support protection mechanisms during an islanding event if the BESS lost two or more (of six) transformers.
- The ability to distinguish high load current from fault current.
- On weak electricity networks power swings could simulate islanding. Hence to identify genuine islanding a topology-based methodology was used.

6.6 Auxiliary Loads and Losses

It is important to consider how the battery is intended to be used and consider the various aspects that comprise the auxiliary loads and losses. This information is a key input to inform how the commercial arrangements then need to be setup.

6.7 Value of Future Battery Systems

Early in the Knowledge Sharing period it was observed that batteries are currently difficult to justify as a standalone investment. The key challenges facing future battery system projects were expected to include reduced FCAS value. Factors seen as potential mechanisms that would improve the value of battery systems over time were increasing network constraints, potential increases in price volatility due to a decrease in dispatchable supply over time, and the introduction of five-minute settlement. It is noted that a large battery system was recently announced by the Victorian Government with a key purpose being improved reliability of the interconnection with SA.

6.8 System Integrity Protection Scheme

Following the SA power system black event in September 2016, maintaining the connection of the Heywood Interconnector during a system event that results in significant generation loss in South Australia has been identified as a high priority.

The System Integration Protection Scheme (SIPS) was introduced to address this risk and is designed to rapidly identify conditions that could otherwise result in a loss of synchronism between South Australia and Victoria. The BESS has been incorporated into the SIPS and is able to provide rapid response on receipt of a SIPS command. The SIPS function of the BESS has been tested and operated correctly.

6.9 Primary Frequency Response (PFR) rule change

Implementing the Primary Frequency Response (PFR) rule change requires changes to the internal logic and control loops. Since the controls of the Dalrymple BESS are finely tuned to provide a wide range of services prior to this Rule change, it will require significant amount of work and testing to implement this additional functionality.

6.10 Cooling Systems

The BESS is a comparatively large indoor installation of batteries and under rapid discharge the temperature can reach 50°C in 1-2 minutes. Close attention must be paid to the air conditioning design and ducting of air flow to optimise the performance of the cooling system.

7. Associated Parties

As South Australia's principal Transmission Network Service Provider (TNSP), ElectraNet is a critical part of the electricity supply chain. It builds, owns, operates and maintains high-voltage electricity assets, which move energy from traditional and renewable energy generators in South Australia and interstate to large load customers and the lower voltage distribution network.

ElectraNet owns and maintains the ESCRI-SA 30 MW 8 MWh battery, which provides both regulated network services and competitive market services.

AGL operates the country's largest electricity generation portfolio and is its largest ASX-listed investor in renewable energy. AGL's diverse power generation portfolio includes base, peaking and intermediate generation plants, spread across traditional thermal generation, natural gas and storage, as well as renewable sources including hydro, wind, landfill gas, solar and biomass.

AGL operates the battery to provide competitive market services.

Advisian is the advisory and specialist consulting arm of Worley and has been involved with the ESCRI-SA Project since its inception in 2013. This work included significant input into the technical and project management components of Phase 1. In Phase 2 and 3 Advisian has been the Knowledge Sharing Partner for the Project.

Appendix A Timeline and Milestones

Awards

12-Sep-19	ENA 2019 Industry Innovation Award
15-Nov-19	2019 South Australia Premier's Awards: Energy Sector - Transformational Innovation

Milestones

13-Apr-17	ARENA Conditional Funding Approval
30-May-17	Request for Proposal issued (revised functional specification reflecting updated revenue streams)
13-Jul-17	Request for Tender issued (containing full commercial terms and more detailed functional descriptions)
15-Aug-17	ARENA Funding Agreement Executed
17-Aug-17	Notice to Proceed - Early works, long lead time items procurement, and design phase
21-Sep-17	Battery Operating Agreement executed
21-Sep-17	EPC contract and Maintenance Service Agreement executed
1-Oct-17	Final Investment Decision by ElectraNet Board
11-Oct-17	Development Approval received
16-Oct-17	Amendment to ARENA Funding Agreement (Funding instalment agreement)
13-Nov-17	Financial close
30-Apr-18	Energisation of BESS
7-Sep-18	Grid-connected commissioning completed
14-Dec-18	Start of commercial operation (Handover to AGL)
5-Apr-19	Islanding with the Wattle Point Wind Farm commissioning completed
14-Dec-20	Two-year knowledge sharing period end

KSRG Meetings

6-Feb-18	Knowledge Sharing Reference Group meeting #1
8-May-18	Knowledge Sharing Reference Group meeting #2
14-Aug-18	Knowledge Sharing Reference Group meeting #3
12-Jun-19	Knowledge Sharing Reference Group meeting #4
3-Mar-20	Knowledge Sharing Reference Group meeting #5
16-Sep-20	Knowledge Sharing Reference Group meeting #6

Site Visits

7-Feb-18	First site visit by KSRG members
15-Aug-18	Second site visit by KSRG members

Presentations

Aug-17	ESCRI-SA presentation to The Electric Energy Society of Australia
Oct-17	ESCRI-SA presentation to NEM Future Forum, Sydney
Nov-17	ESCRI-SA presentation to Large Scale Solar and Storage Conference
Dec-17	ESCRI-SA presentation to Australian Solar and Energy Storage Congress
May-18	ESCRI-SA Presentation on Battery storage to improve transmission network resilience, Adelaide
Jun-18	ESCRI-SA presentation on Battery Energy Storage Lessons Learned, Sydney
Nov-19	ESCRI-SA Presentation on Dalrymple Battery Energy Storage System, Hobart
Feb-20	ESCRI-SA presentation to API Summer School - February 2020
Apr-20	ESCRI-SA presentation to SEPA (US based Smart Electric Power Alliance) Energy Storage WG
Jul-20	Presentation by ElectraNet and Hitachi ABB Power Grids at a webinar on Grid Forming Energy Storage

Reports

Phase 1	(Previous ARENA supported project)
Nov-14	Phase 1 - Milestone 1 Report - Regulatory Overview
Nov-14	ESCRI-SA Basis of Design, Energy Storage Device
Jan-15	Phase 1 - Milestone 2 Report - Site Selection
May-15	ESCRI-SA - State of the Art in Energy Storage – Report
Jun-15	Phase 1 - Milestone 3 Report - Commercial Framework
Jun-15	Phase 1 - Milestone 3 Report - Energy Storage Systems
Aug-15	ESCRI-SA Mathematical Model
Dec-15	Phase 1 - Milestone 5 General Project Report
Phase 2	
May-18	ESCRI-SA Project Summary Report – “The Journey to Financial Close”
Oct-18	ESCRI-SA Project Summary Report “From Financial Close to Commissioning”.
Phase 3	
Jul-19	ESCRI-SA Operational Report No. 1
Aug-19	ENA Innovation Award 2019 - ElectraNet Application for ESCRI-SA

Oct-19	Technical Article - Wind Integration Workshop - 30MW BESS
Feb-20	ESCRI-SA Operational Report No. 2
Aug-20	ESCRI-SA Operational Report No. 3
Aug-20	Technical Article - CIGRE48 Grid Forming BESS Case Study
Feb-21	ESCRI-SA Operational Report No. 4
Mar-21	ESCRI-SA Final Knowledge Sharing Report

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