Lake Bonney BESS

Final Knowledge Sharing Report

Feb 2023

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Executive Summary

This report summarises the entirety of the Lake Bonney BESS from its development through to the completion of its second year in operation in December 2021. The Lake Bonney BESS is a 25MW / 52MWh energy storage system that utilises Tesla's Powerpack battery technology and was installed alongside Iberdrola Australia's operational Lake Bonney wind farms that have a combined capacity of 278.5MW.

Technical Performance

System availability for the Lake Bonney BESS has remained high throughout the first two years of operations, with a slight decrease in reported availability due to a change in reporting method and not a decline in performance.

Despite a number of AEMO constraints including the Lake Bonney BESS, they have rarely impacted upon its dispatch in the first two years of operation, with the majority of constraints that have impacted the dispatch of the BESS occurring during islanded network conditions. Limited impacts have also been observed for the transformer load management constraint applied at site, with dispatch decisions of the BESS impacted around only 10 times during the first two years of operations.

There were no safety or environmental incidents of note throughout the development, construction, commissioning, and operations of the Lake Bonney BESS to date, highlighting the strong safety performance of Iberdrola Australia at the Lake Bonney site and its existing wind farms.

Financial Performance

Within its first two years of operations, Lake Bonney BESS' earnings were well correlated with periods of increased volatility, none more so than in February 2020 when the SA region was separated from the rest of the NEM, and Lake Bonney BESS earned $5.9m in this month alone.

FCAS markets presented the largest revenue opportunity for Lake Bonney BESS in its first two years of operation, with revenues earned across the three main markets of energy, regulation FCAS and contingency FCAS at 15%, 35% and 50% of total revenues respectively. Raise FCAS services were slightly more valuable than lower services, due to the increased value of raise contingency FCAS in comparison to the lower contingency FCAS markets.

Key Operational Events

The key operational events that have occurred in the first two years of Lake Bonney BESS' operation:

1. January 31st 2020 Separation Event

2. Implementation of 5-Minute Settlement
3. Causer Pays Factor trial

are summarised in the corresponding sections, with further details available in the associated Operational Reports already published.

In addition to these operational events, an ongoing assessment of the Causer Pays Management provided by Lake Bonney BESS is also provided.

Summary of Project Risks and Treatment

A summary of the high-level risks of the project across the development, construction and operations phases are detailed in the corresponding section. Risks that were specific to the Lake Bonney BESS as a brownfield development were focussed upon construction risks, and included:

- ✓ Presence of existing underground services within construction areas
- ✓ Management of existing wind farm operations to coordinate heavy-vehicle movements
- ✓ Coordinated plant outages to undertake commissioning of electrical assets

Overall Lessons Learnt and Recommendations

A number of lessons learnt and recommendations were identified during the development, construction and operation phases of the Lake Bonney BESS and summarised in this report.

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Glossary

Acronym	Description
AC	Alternative Current
AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
BoP	Balance of Plant
BRC	Building Rules Consent
C&I	Commercial and Industrial
COD	Commercial Operation Date
CPF	Causer Pay Factor
CPP	Consolidated Power Projects Australia Pty Ltd
DI	Dispatch Interval
DC	Direct Current
EPC	Engineering, Procurement and Construction Contract
ESCOSA	Essential Service Commission of South Australia
EWA	Early Works Agreement
FCAS	Frequency Control Ancillary Services
FID	Final Investment Decision
FSSIA / FIA	Full System Strength Impact Assessment / Full Impact Assessment (interchangeable)
GPS	Generator Performance Standards
HPR	Hornsdale Power Reserve
HSE	Health Safety Environment
IFC	Issued for Construction

LBWF	Lake Bonney Wind Farm
LGC	Large-Scale Generation Certificate
LPs	Linear Programs
MPWA	Master Preliminary Works Agreement
MV	Medium Voltage
MW	Mega Watt
MWh	Megawatt Hour
NEM	National Electricity Market
NOFB	Normal Operating Frequency Band
NSP	Network Service Provider (TNSP = Transmission NSP)
O&M	Operation and Maintenance
OCGT	Open Cycle Gas Turbine
OEM	Original Equipment Manufacturer
OTR	Office of the Technical Regulator (of South Australia)
PFR	Primary Frequency Response
PoE	Probability of Exceedance
PSCAD	Power Systems Computer Aided Design
PSSE	Power Systems Simulator for Engineering
pu	per unit
PV	photovoltaic
RTF	Renewable Technology Fund (South Australia grant program)
SCAP	State Commission Assessment Panel (of South Australia)
SCR	Short Circuit Ratio
SoC	State of Charge
SoE	State of Energy (same as SoC)
TCA	Transmission Connection Agreement

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1. Purpose and Distribution

1.1 Purpose of Document

This document summarises the project learnings from its development through to the completion of the second year in operations of the Lake Bonney BESS project, a 25MW / 52MWh Battery Energy Storage System (**BESS**).

This project received $5 million in funding from ARENA as part of ARENA's Advancing Renewables Program and $5 million in funding from the South Australian Government's Renewable Technology Fund.

This document is to focus on the following areas relating to the BESS, including:

- Technical performance
- Financial performance
- Key operational events
- Summary of project risks and treatment
- Overall lessons learned

1.2 Distribution of Report

This document is intended for the public domain and has no distribution restrictions.

The intended audience of this document includes:

- Project developers
- Renewable energy industry participants
- General public
- Equipment vendors
- General electricity sector members
- Government bodies
- ARENA

2. Knowledge Sharing Plan

This document represents the third and fourth reporting deliverable under the Knowledge Sharing Plan that forms part of the funding agreement between Iberdrola Australia and ARENA.

The full schedule of knowledge sharing deliverables associated with the project are given in Table 1 below.

Table 1 Knowledge Sharing Commitments

Deliverable	**Timeline**
Project Summary Report	Publicly available
Industry Presentation on Project Summary Report	Delayed due to COVID-19
Project Web Portal	Publicly available
Operational Report #1	Publicly available
Industry Presentation on Operational Report #1	Cancelled due to COVID-19
Operational Report #2	Publicly available
Industry Presentation on Operational Report #2	Delayed due to COVID-19
Operational Report #3	Publicly available
Operational Report #4	Publicly available
Final Knowledge Sharing Report	This document

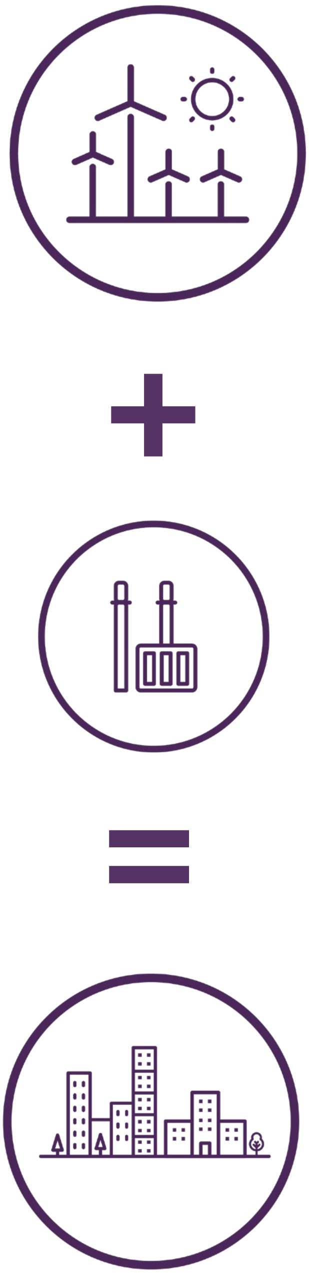
3. Project Introduction

3.1 Iberdrola Australia

We generate and source renewable energy

We generate renewable energy from our fleet of owned renewable generators. With a total of 987MW of operational nameplate capacity, it is one of the largest renewable energy fleets in Australia.

We also source renewable energy from third parties where we contract to purchase their output under long term Power Purchase Agreements. This diversifies our supply and enables us to serve a growing customer base.



We add value by firming

Because renewable energy is inherently intermittent, and because customers need electricity on demand, flexible, fast-start assets are needed to manage intermittency risks.

Our firming portfolio comprises Smithfield Open Cycle Gas Turbine, a 123MW gas peaker in NSW, the Lake Bonney Battery Energy Storage System, a 25MW/52MWh battery in SA, and the South Australia Gas Turbines, 120MW of dual-fuel peaking capacity in SA.

Firming assets operate with very low levels of utilisation (sometimes as low as 2%) and because they are used to manage intermittency risk, Iberdrola Australia's economic outcomes are not directly correlated with their output.

We provide customers with reliable and competitively priced clean energy

By combining a diversified fleet of renewable generators with a portfolio of flexible, fast-start assets, we can provide customers with firm supplies of clean energy in a way that minimises their bills.

Because more than 95% of our generation is renewable and because we can still serve customers on demand, our model has been called 'the utility of the future'

3.2 Lake Bonney BESS

The Lake Bonney BESS is a 25MW / 52MWh energy storage system that utilises Tesla's Powerpack battery technology. The Lake Bonney BESS was installed on Iberdrola Australia's operational Lake Bonney wind farms (**LBWF**) as a brownfield development.

3.2.1 Key Project Objectives

The key project objectives of the Lake Bonney BESS were to allow Iberdrola Australia to:

— firm up Iberdrola Australia's generation capacity from LBWF to increase Iberdrola Australia's contracting capacity with commercial and industrial (**C&I**) customers by between 50% and 75% of the battery's power output capacity, to increase retail competition for C&I customers in South Australia;

— deliver system security services in the South Australian region of the NEM by participating in the regulation and contingency Frequency Control Ancillary Services (**FCAS**) markets, as well as providing a fast frequency response (**FFR**) when a market arises; and

— seek to use the Lake Bonney BESS to reduce LBWF's Causer Pays Factor (**CPF**) and curtailed generation losses.

3.2.2 Technical Overview

The key technical characteristics of the operational Lake Bonney BESS are outlined in Table 2 below.

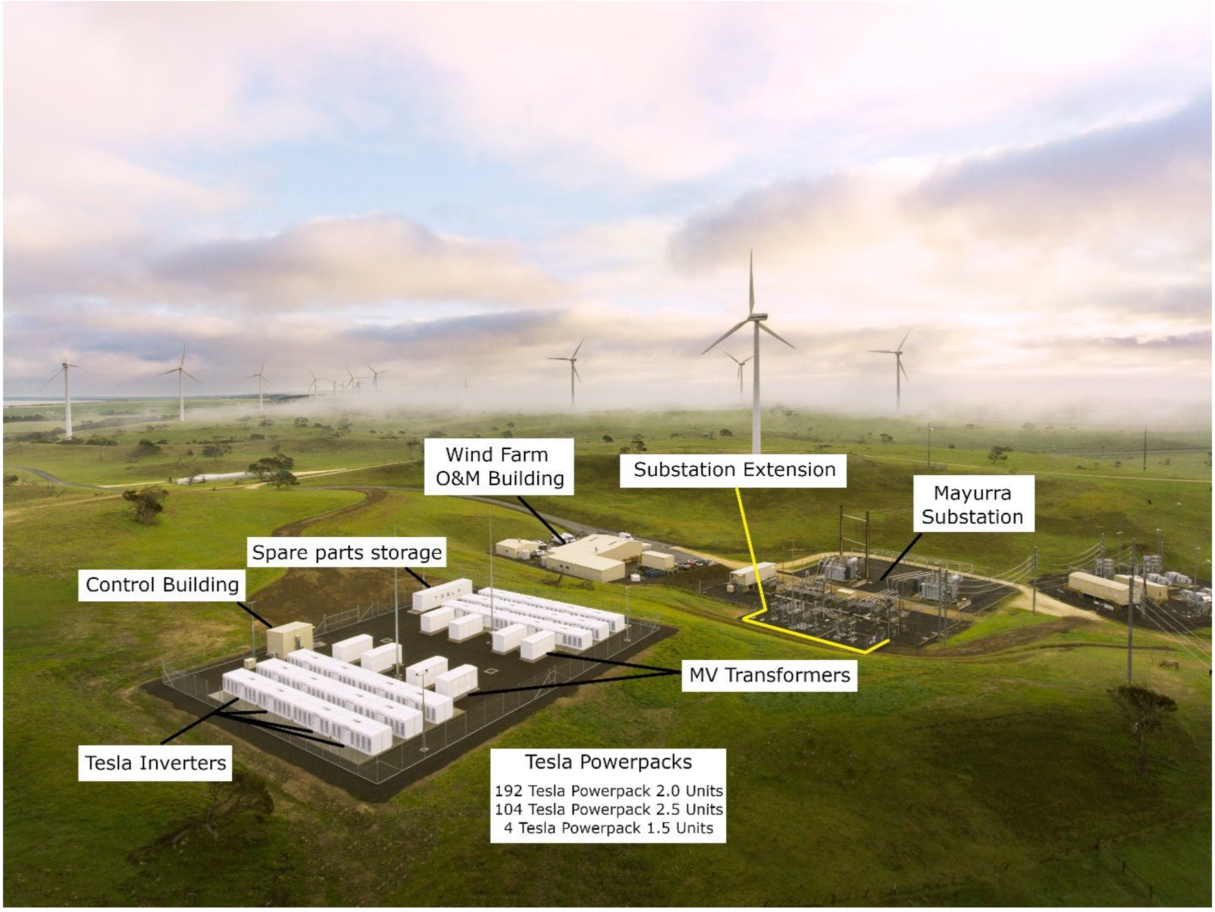
Table 2 Summary of key technical parameters of the Lake Bonney BESS

Technical Parameter	**Summary**
Nominal Power Capacity	+/-25MW (charge and discharge power)
Nominal Energy Storage Capacity	52MWh
Power Capacity Degradation	None
Energy Storage Capacity Degradation	~2-3% per annum
Battery Units	192 Tesla Powerpack 2.0 Units 104 Tesla Powerpack 2.5 Units 4 Tesla Powerpack 1.5 Units
Inverter Units	48 Tesla inverters

System Voltages	Inverter AC voltage: 440V Kiosk Transformer: 33kV
Balance of Plant	8 ABB 3.5MVA 440V/33kV transformers 33kV AIS switchgear Control building DC, MV and control cabling
Point of Connection	33kV extension bay at 33kV/132kV Mayurra substation

An overview of the completed Lake Bonney BESS is shown in Figure 1 below.

Figure 1 Lake Bonney BESS site overview



4. Technical Performance

4.1 System Availability and Outages

System Availability

Throughout the first two years of operations, the Lake Bonney BESS was able to maintain a high level of availability at the plant level as outlined in Table 3 below.

Table 3 Monthly system availability

Month	Availability (%)
Jan-21	100.00
Feb-21	100.00
Mar-21	100.00
Apr-21	100.00
May-21	100.00
Jun-21	100.00
Jul-21	100.00
Aug-21	100.00
Sep-21	96.90
Oct-21	100.00
Nov-21	99.90
Dec-21	100.00
Jan-21	99.56
Feb-21	99.92
Mar-21	99.36
Apr-21	100.0
May-21	100.0
Jun-21	99.90
Jul-21	99.98
Aug-21	99.80
Sep-21	100.0
Oct-21	98.22
Nov-21	99.50
Dec-21	99.94

Availability of the plant is calculated as the maximum of the available charge or discharge power for each dispatch interval at the point of connection as a percentage of the nameplate capacity, averaged for each monthly interval. It should be noted that the calculation of availability was varied from July 2020 onwards, leading to the increase in periods were an availability slightly below 100% was recorded.

System Outages

Table 4 summarises the planned outages and works at Lake Bonney BESS for the first two years of operations.

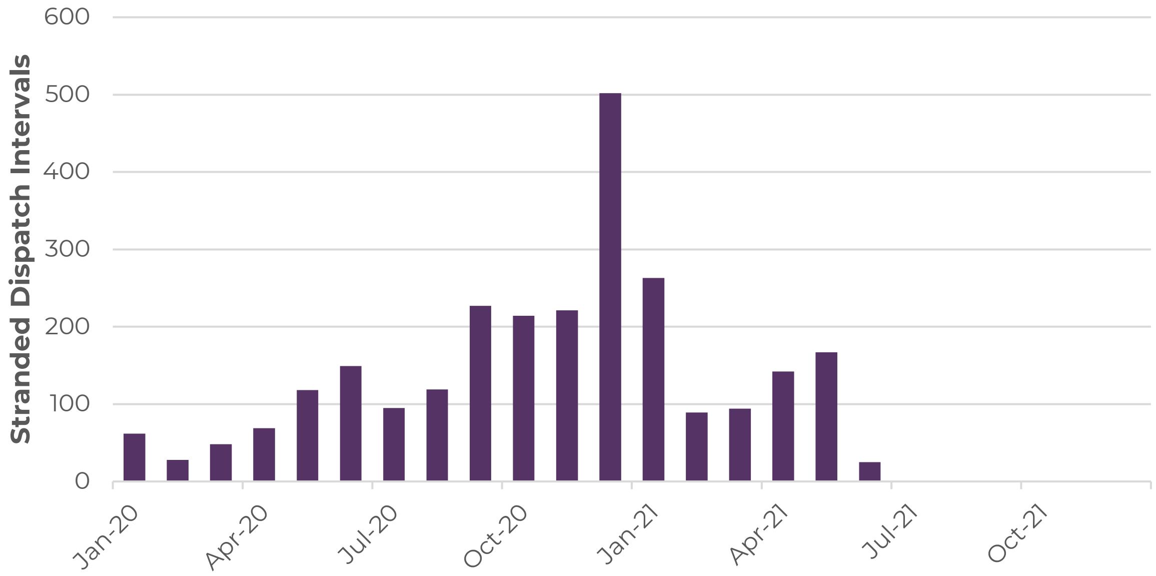
Table 4 Lake Bonney BESS planned outages

Description	Start Date	End Date
The BESS output down by 3.9 MVA for the period of the outage.	4/08/2020	4/08/2020
Firmware upgrade, including RTAC update and controls testing	5/08/2020	5/08/2020
Minor works to address faulted pod, with no impact to maximum MW output.	28/08/2020	28/08/2020
Inspection and maintenance of the MV transformers alongside cleaning and inspection of electrical BoP	23/09/2020	23/09/2020
No impact on capacity or availability during the works	3/11/2020	3/11/2020
Testing to validate contractual energy retention by Tesla	4/11/2020	4/11/2020
Battery unavailable during firmware update	5/11/2020	5/11/2020
1 powerpack offline at a time. No impact on Availability.	10/11/2020	11/11/2020
Tesla Inverter Maintenance	11/01/2021	11/01/2021
Minor Inverter Maintenance	22/02/2021	22/02/2021
Annual HV Maintenance	23/03/2021	24/03/2021
Single inverter outage for firmware update	June 2021	
3 inverter units offline for rectification of remote CB operation issue.	July 2021	
Single inverter unit outage for door replacement	23/08/2021	24/08/2021
Tesla inverter maintenance	02/12/2021	14/12/2021

No unplanned outages have occurred during this period.

As shown in Figure 2 below, the stranding issue that was occurring at Lake Bonney BESS where it was registering an initial MW value outside of +/-25MW has subsequently been fixed in the second half of 2021.

Figure 2 Lake Bonney BESS stranded dispatch intervals per month



4.2 Dispatch Constraints

AEMO Constraints

Constraints that have been described by AEMO that include the Lake Bonney BESS in the first two years of operations are shown in Table 5 below.

Table 5 AEMO constraints that include Lake Bonney BESS

Constraint Type	Number of Constraints	Constraints That Have Bound	Number of DIs That Constraints Bound
FCAS	14	6	4,589
OTHER	23	8	2,899
STABILITY	435	28	1,256
THERMAL	116	27	3,372
VOLTAGE	326	14	4,343

The Lake Bonney BESS had been included in 877 Thermal, Voltage Stability, and Transient Stability constraints at the time it was two years into operations. In this period, these types of constraints have bound the Lake Bonney wind farms and BESS for 8,791 DIs (~3.5% of the time). These constraints rarely impact the dispatch of the BESS, as it spends most intervals operating in the FCAS markets rather than the energy market.

The 14 FCAS constraints are designed to maximise the contingency response during an SA separation event, and all periods of this constraint binding were experienced during the February 2020 separation event.

The Other constraint category typically related to constraints in periods when SA is islanded, but also contains a key SA system strength constraint that limits the combined output of semi-scheduled generators under certain conditions. Lake Bonney BESS was added to this constraint on 3/09/2021 and subsequently removed on 25/10/2021, and this period accounted for ~85% of the intervals that Other constraints bound.

Site Constraints

ElectraNet transformer load management

The transformer (**TX1**) at the Mayurra substation that the Lake Bonney BESS connects into is shared with LBWF stages 2B and 3.

TX1 has a continuous limit of 145MVA. However, this limit can be exceeded for up to 10 minutes to a maximum of 156.1MVA, but only for the purpose of providing raise contingency FCAS through the Lake Bonney BESS. Lake Bonney BESS has the necessary control logic implemented to ensure that it doesn't exceed the transformer limits.

During the first two years of operations, there were 353 ten-minute intervals (~60 hours) where the generation of LBWF connected to TX1 exceeded 115MVA, corresponding to 0.32% of the time. On approximately 10 occasions, the operational strategy of Lake Bonney BESS was changed to allow Lake Bonney 2 & 3 wind farms to be released to full output. Over the course of two years of operations, this level of load management has had a negligible impact on the economic performance of both the Lake Bonney BESS and wind farms.

4.3 Safety and Environmental Performance

There were no major safety or environmental incidents of note throughout construction, commissioning and the first two years of operations, with physical interactions at Lake Bonney minimised amid the continuing COVID-19 pandemic in line with Iberdrola Australia's protocols.

All high voltage switching activities involving the BESS are managed under the existing LBWF procedures by LBWF maintenance personnel. The familiarity of the personnel with the site facilities helps to minimise the risk of undertaking such works.

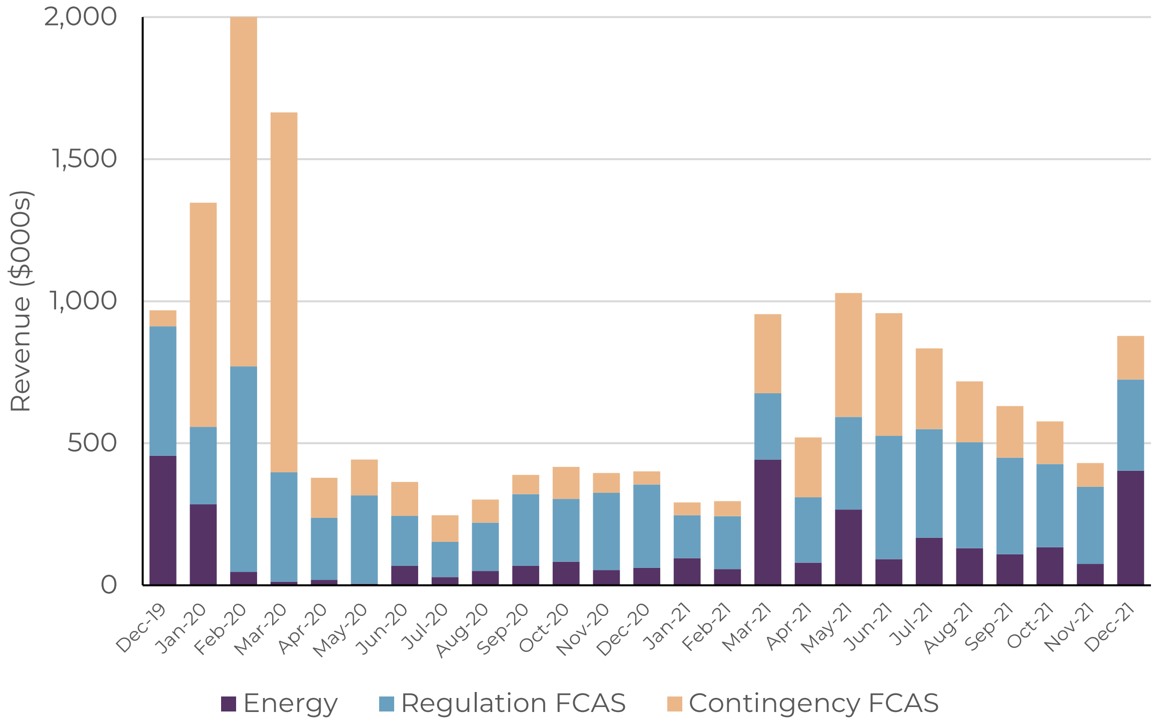
5. Financial Performance

The revenue figures shown below are compiled using operating data for the battery from AEMO's MMS database (which has not been verified for accuracy) and AEMO's settlement procedures for the applicable revenue sources. The presented revenue results for the battery may not reflect actual outcomes due to errors in underlying data or due to contract positions held by Iberdrola Australia. Accordingly, this information should not be used as an indication of the net revenues earned by Iberdrola Australia from the battery's operations.

Market revenue by month

The revenue earned by the Lake Bonney BESS for each month of the first two years of operations is shown in Figure 3 below.

Figure 3 Lake Bonney BESS revenue by month in the first two years of operation



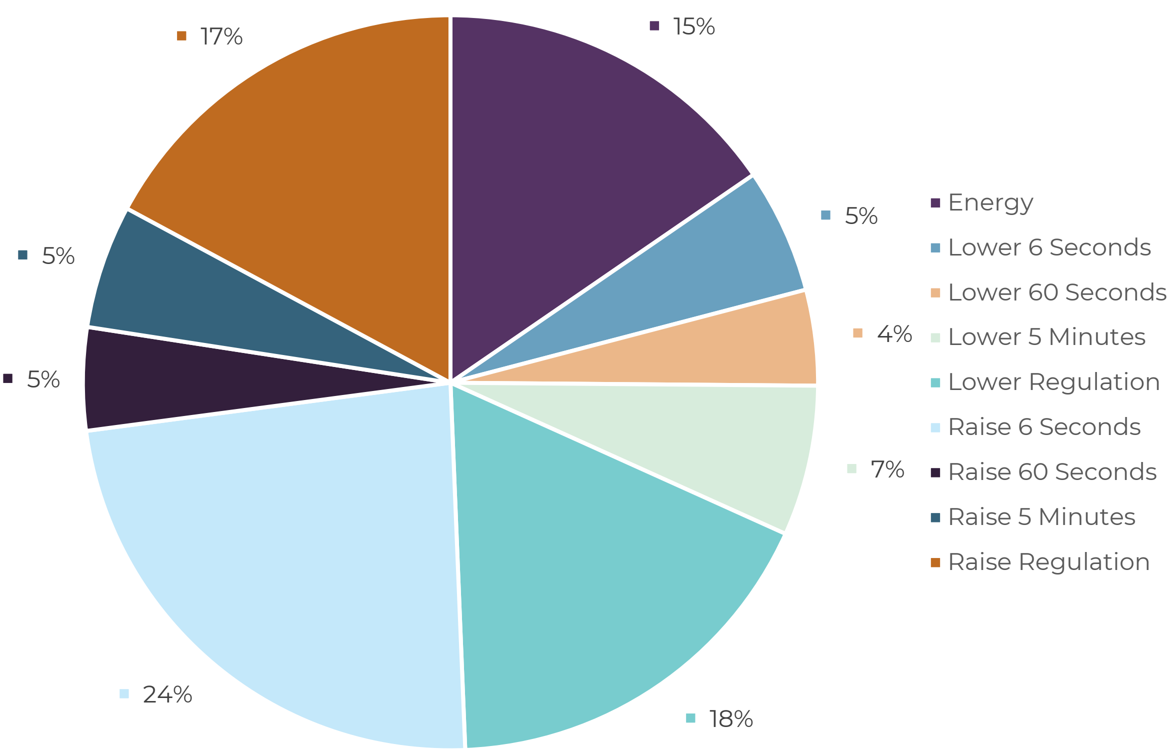
Throughout the first two years of operations, increased monthly revenues were well correlated with periods of increased volatility, none more so than February 2020 when the SA region was separated from the rest of the NEM. In this month, Lake Bonney BESS earned $5.9m, with the majority of this revenue coming from participation in the contingency FCAS markets during the separation event.

Further increases in revenue are notable following an incident at Callide Power Station on 25th May 2021. This loss of generation led to an under-frequency load shedding event and extreme pricing in the short term, as well as increased market volatility in the medium term across the NEM (with the largest impact seen in the QLD region).

Market revenue by service

The revenue earned by the Lake Bonney BESS in first two years of operations by service is shown in Figure 4 below.

Figure 4 Lake Bonney BESS revenue by month in the first two years of operation



As noted in the corresponding Operational Reports, FCAS markets presented the largest revenue opportunity for Lake Bonney BESS in its first two years of operation, with revenues earned across the three main markets of energy, regulation FCAS and contingency FCAS at 15%, 35% and 50% of total revenues respectively. Raise FCAS services were slightly more valuable than lower services, due to the increased value of raise contingency FCAS in comparison to the lower contingency FCAS markets.

6. Key Operational Events

A summary of the key operational events that occurred within the first two years of operation of the Lake Bonney BESS are provided below, with further detail available in the relevant Operational Report.

6.1 January 31st 2020 Separation Event

Operation of Lake Bonney during the fault

Immediately prior to the separation event, the Lake Bonney BESS was charging at ~10MW, and the LBWF was generating at ~140MW. Immediately following the event, frequency was seen to increase to a maximum of 51.3Hz, with a maximum rate of change of frequency (**ROCOF**) observed of 0.75Hz/s.

Lake Bonney BESS performed as expected during the event and provided a contingency FCAS response as per its droop characteristic. As the maximum ROCOF observed during that event was 0.75Hz/s, and with the 1.7% droop setting of the BESS (providing 25MW following a 0.85Hz deviation), the maximum rate of change of the BESS' active power response was ~22MW/s. This is well within the response time capability of the plant.

LBWF also performed as expected during the event. LBWF stage 1 was generating approximately 30MW and in accordance with its over-frequency generation shedding (**OFGS**) scheme, it disconnected when the frequency reached the threshold. LBWF stages 2 and 3 rode through the event as the frequencies at which their respective OFGS scheme is activated are higher than the maximum frequency recorded during the event.

Operation of Lake Bonney during islanded conditions

Within 30 minutes of the separation event, LBWF stages 2 and 3 were constrained to 0MW of generation (with LBWF stage 1 having already disconnected due to its OFGS settings). LBWF was constrained off by AEMO for the duration of the February separation event and did not begin generating again until 18th February.

Throughout the event, the battery was utilised under the instruction of AEMO (either through directions or constraints) that limited the BESS to participate mainly in the contingency FCAS markets. This approach was consistent with AEMO's treatment of the three utility-scale batteries in the region.

On the 3rd February, AEMO introduced constraints that limited Lake Bonney BESS regulation FCAS capacity to 0MW in order to ensure that AEMO could access as much contingency FCAS response as possible. On the 5th February, additional constraints were added which limited energy availability to 2MW and required the BESS to maintain a state of charge of 50% +/- 20%. On the 13th February, the constraints relating to regulation FCAS were relaxed to allow 5MW of raise or lower regulation to be supplied.

Impact of separation event on Iberdrola Australia's SA portfolio

During the islanding of the SA region in February 2020, the additional revenue earned by Lake Bonney BESS was above expectation due to high FCAS prices, which broadly offset the economic impact of the curtailed production at LBWF due to AEMO constraints. This included the cost of covering Iberdrola Australia's contract exposure with C&I customers in the spot market, and the increased reimbursement costs paid due to the Lake Bonney market participant Causer Parys Factor (**CPF**).

While the cost impacts on Iberdrola Australia throughout the separation event broadly offset as noted above, they did highlight that there are certain circumstances where Lake Bonney BESS may not be available to provide a physical hedge for Iberdrola Australia's portfolio. During the 31st January separation event, this was true for both the energy and regulation FCAS markets.

While the energy market risk posed by separation can't be reduced, the exposure of the LBWF market participant to regulation FCAS reimbursement costs through its CPF can be managed. However, as CPF is determined ahead of time, to be covered during the separation event Lake Bonney BESS would have needed to have been operated with a tighter frequency deadband in the weeks leading up to the separation event, and not during the event itself.

6.2 Causer Pays Factor Management Trial

CPF Options Explored by Iberdrola Australia

Iberdrola Australia initially explored two options that would reduce the CPF of LBWF.

The first option was to utilise the BESS to ensure that the LBWF appeared to follow its linear trajectory. This would require Lake Bonney BESS to calculate the difference between LBWF's actual output and its linear trajectory, and account for this difference as either a generator or load. This option was not preferred as it would cancel out any beneficial response of LBWF at times where its deviation from its linear trajectory was improving its CPF. The operation of the BESS independent of any system frequency response, provided due to a droop setting or an AGC dispatch signal, also raised concerns around the potential non-compliant operation of the BESS as well as the risk of Lake Bonney BESS accruing a negative CPF due to the balancing service it would provide.

The second option explored by Iberdrola Australia was to increase the responsiveness of the Lake Bonney BESS to frequency deviations, by tightening the frequency droop response's deadband from 50Hz +/- 0.15Hz. In this option, the Lake Bonney BESS would respond independently of the LBWF, preventing the issue identified above where the Lake Bonney BESS could fight against the LBWF when they are providing a beneficial response. Utilising the frequency response option would ensure that the response was proportional to the size of the frequency deviation and could be implemented and adjusted using existing frequency response parameters. This option was therefore preferred by Iberdrola Australia.

CPF Trial

The causer pays trial was conducted for two weeks, from 9:00 on the 10/08/2020 until 9:00 on the 24/08/2020. The trial used the following sources for its data:

- The 5-minute DUID-level CPFs (4 for each dispatch interval) are downloaded from AEMO's Causer Pays Contributions Factor webpage[1] and used to calculate the CPF improvement;
- FCAS recovery cost data is queried from AEMO's MMS database and used as the basis for the expected cost savings; and
- Energy throughput is calculated using AEMO's 4-second causer pays data and is used to determine the cost of providing CPF management.

Lake Bonney BESS' benchmark contribution to the Lake Bonney participant's CPF is shown in the **Outside Trial** row of Table 6, as the average 28-day factors attributed to Lake Bonney BESS for the period between 17/02/2020 and 11/10/2020 (excluding the trial period).

The high average positive number attributed to Lake Bonney BESS' LEF/REF values indicates the positive impact that the BESS has on frequency when providing regulation FCAS, but these two factors do not contribute to the overall CPF of the Lake Bonney market participant (as they are already compensated through the regulation FCAS markets). The LNEF/RNEF values outside of the trial period are close to 0; as Lake Bonney BESS accurately tracks against its energy targets. As such, Lake Bonney BESS does not accrue a large negative factor, but also does not accrue a large positive factor as it does not assist frequency within the NOFB when not providing regulation FCAS.

The changes to Lake Bonney BESS' deadbands for the CPF trial meant that a large positive factor could be accrued, as the BESS would now provide a proportional frequency response within the NOFB when not providing regulation FCAS. Lake Bonney BESS' contribution to the Lake Bonney participant's CPF during the trial period is shown in the **During Trial** row of Table 6 below (extrapolated to reflect a 28-day period), which shows a net improvement in the combined factor of 39.

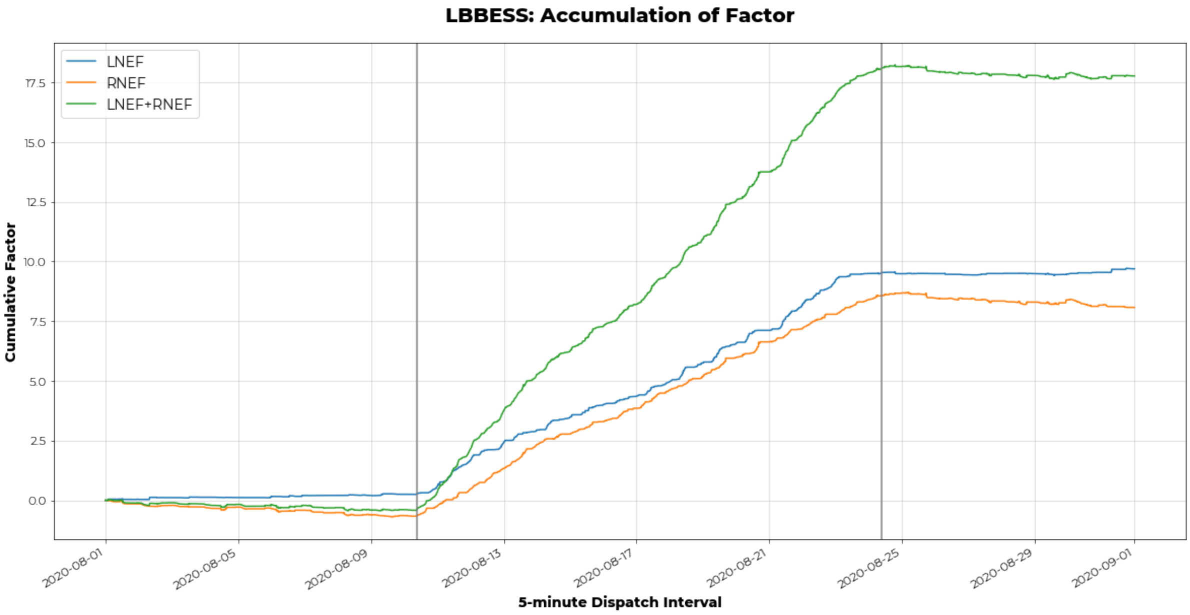
Table 6 Lake Bonney BESS average 28-day participant contributions during and outside trial

	LEF	LNEF	REF	RNEF	Combined Factor (LNEF+RNEF)
During Trial	113	19	159	19	**38**
Outside Trial	121	1	156	−2	**−1**
Net Improvement	−8	18	3	21	**+39**

[1] AEMO | Ancillary services causer pays contribution factors

The variation in LEF results during and outside of the trial was caused by the different average enablement of Lake Bonney BESS in this market during and outside of the trial period. The justification for extrapolating the trial period results over a 28-day period is highlighted in Figure 5 below, which shows that the positive LNEF and RNEF values were accrued consistently and linearly throughout the trial period.

Figure 5 Accumulation of Lake Bonney BESS' RNEF and LNEF values during CPF trial



Energy throughput

In addition to accumulating positive LNEF/RNEF values, tighter deadbands increased the cycling of the battery. The additional throughput due to the frequency response changes was needed to calculate the effective value of CPF management, so that it can be compared against the value of using battery cycles for energy and FCAS.

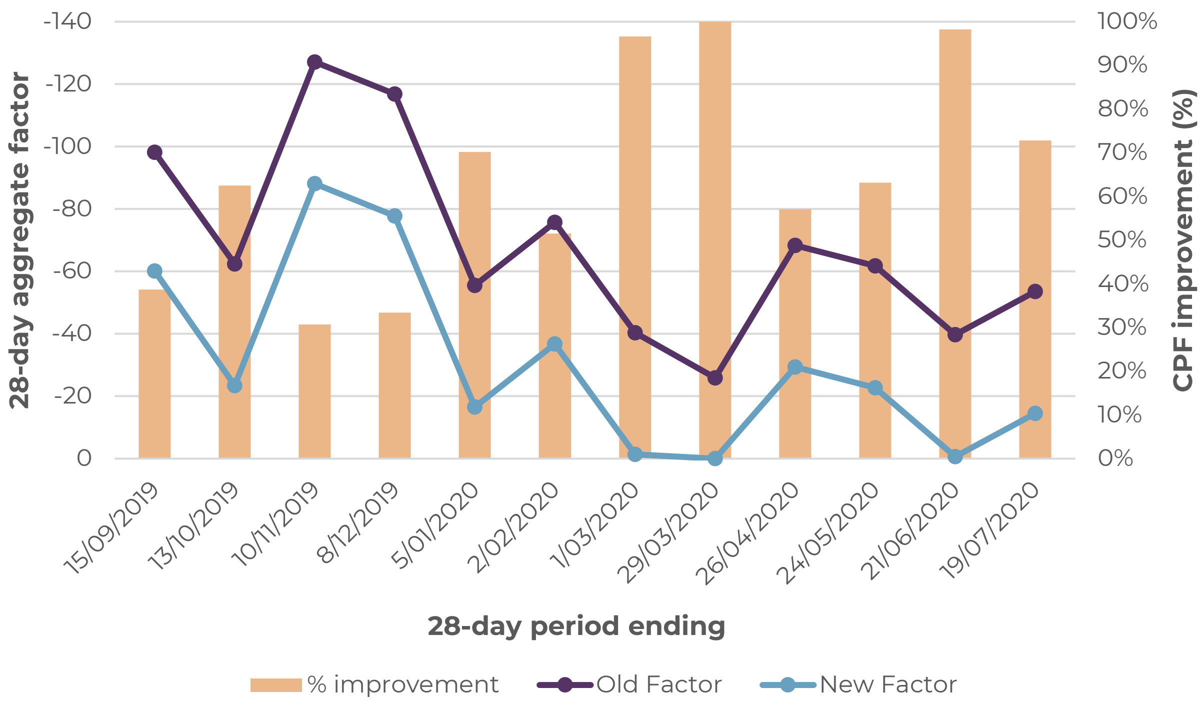
The effects of tightening the frequency deadbands at Lake Bonney BESS on throughput was calculated using the baseline average daily throughput expected due to the reconstructed AGC data and compares this to the actual response measured during the CPF trial. The additional average daily energy throughput of Lake Bonney BESS due to the tightened deadbands of +/- 0.035Hz during the CPF trial was 5.16MWh, which is equivalent to ~37 cycles over an entire year.

Validation of CPF strategy and modelling

The CPF trial conducted over the two-week period was able to validate Iberdrola Australia's CPF management strategy, with Lake Bonney BESS clearly demonstrating the capability to accumulate large, positive LNEF/RNEF values to offset the overall LBWP market participant's CPF.

If the positive factor of +39 (calculated in Table 6) earned by Lake Bonney for an indicative 28-day period was applied over the last year of factors, the CPF recovery cost exposure of the LBWP market participant would have been improved (reduced) by between 31% and 100% (averaging 65%), as shown in Figure 6 below.

Figure 6 Reduction in Lake Bonney market participant's CPF exposure



The CPF trial results also validated Iberdrola Australia's initial modelling approach to calculate the potential CPF benefit, with both the positive factor accumulated and the additional energy throughput experienced aligning with the expectations of the desktop models. This will allow for Iberdrola Australia to compare different CPF management strategies in the future based on a number of market sensitivities with confidence that the modelled results will match the observed performance of Lake Bonney BESS.

Impact of PFR and other key factors

While the trial highlighted that CPF management could be undertaken with Lake Bonney BESS, several key factors that influence the value of this strategy continue to change. The most notable of these factors is the frequency distribution of the NEM, which has changed significantly since the implementation of mandatory PFR.

While the tightened distribution of frequency will reduce the energy throughput due to CPF management, it will also decrease the potential opportunity for Lake Bonney BESS to help correct frequency deviations, resulting in a lower positive factor and reduced cost savings (as discussed further in Section 6.4).

6.3 Implementation of 5-Minute Settlement Rule

Modelling Methodology and Limitations

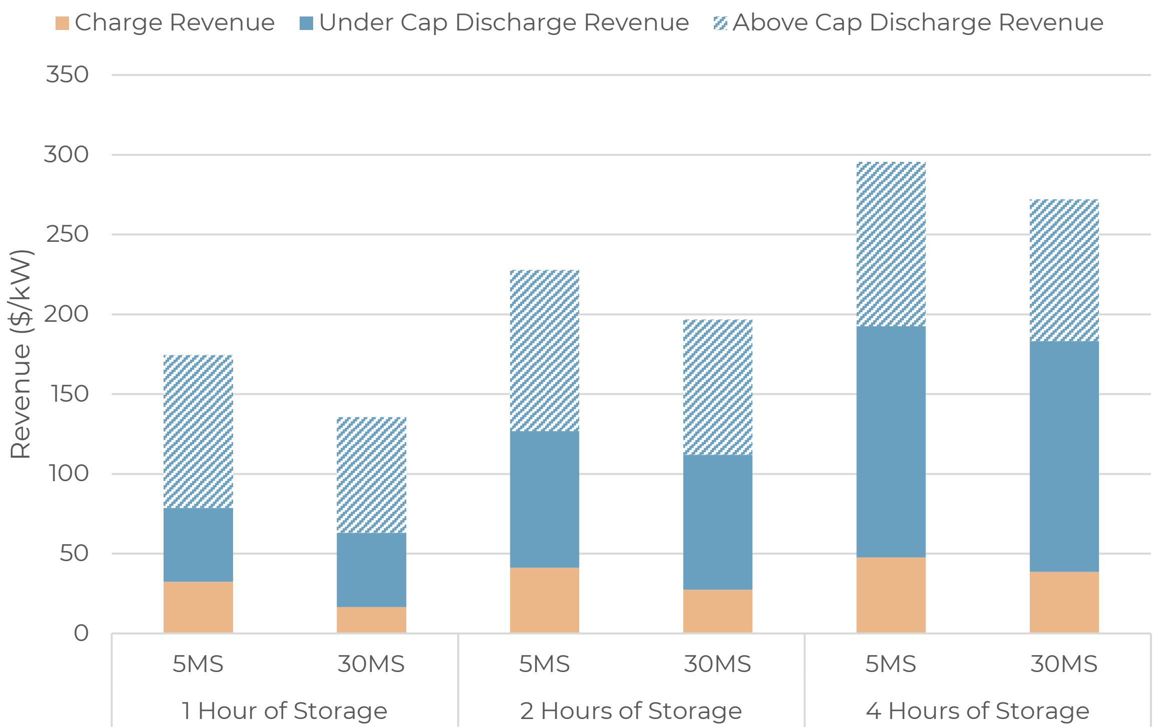
To better understand the economic opportunity that the 5-minute settlement (**5MS**) rule change provides to batteries, Iberdrola Australia has undertaken analysis on the revenue opportunities available under the previous 30-minute settlement (**30MS**) rules in comparison to the new settlement period.

While this method is not entirely reflective of the ongoing market dynamics under 5-minute settlements as it utilises 9 months of prices when 30-minute settlement was still implemented, it should still provide the indicative benefit of the new settlement rule.

Modelling Results

The modelled results of 1, 2 and 4 hours of storage battery systems in the SA region of the NEM in 2021 operating solely in the energy market are shown in Figure 7. The distinction between under cap and above cap discharge revenues are made for the relevant prices under either 5-minute or 30-minute settlement.

Figure 7 Energy-Only Battery Revenues across 2021 in SA Region



Modelling Analysis

From the above results, it is shown that the increases in revenues under 5MS are mainly realised through above cap discharge revenues and charging revenues (i.e. charging during negative price periods). The increase in above-cap revenues is due to two main factors; firstly, the occurrence of prices above $300/MWh under 5MS is higher than under 30MS. With increased frequency in these events (932 dispatch intervals under 5MS compared with 702 dispatch intervals (117 trading intervals) under 30MS), there are clearly more opportunities for additional revenue to be earned within this category.

The second factor influencing above-cap revenues between 5MS and 30MS is the ability of a battery to better manage its state of charge during prolonged high-price events. With prices no longer averaged over a 30-minute interval, the optimal dispatch of a battery no longer requires a full discharge response for this duration. Instead, the battery has increased flexibility to charge and discharge in accordance with each 5-minute dispatch interval.

The above flexibility within high-price events is also a major contributing factor in the relative increases in revenue between 30MS and 5MS across different hours of storage. While a large increase in available revenue is seen for a 1 hour of storage battery (29% increase), this reduces to only a 9% increase when evaluating a 4 hour of storage battery.

The other increased source of revenue seen in the analysis was the increased charging revenues available under 5MS in comparison to 30MS, earned by charging through negative price periods. These opportunities are expected to decrease into the future, as the historical behaviours seen under 30MS of bidding to -$1,000/MWh are no longer motivated.

Comparison of Actual Performance Against Optimal Dispatch

In comparing the actual energy revenues against the modelled optimal response of an energy-only battery within the first three months of 5MS from October 2021 to December 2021, it is important to consider the following key factors:

1. The optimal modelled response has perfect foresight of prices, allowing for the battery to manage its state of charge to capture as much value from high-price periods as possible as it is aware of exactly when they will happen and for how long. The actual revenues earned by Lake Bonney BESS are reliant on the real-time information available to the system to guide its dispatch to maximise revenue, leading to periods where unforecasted price spikes are missed or the battery's state of charge is not high enough to discharge throughout of a high price event.
2. While the optimal modelled response is only focussing on dispatch into the energy market, Lake Bonney BESS is being co-optimised across the energy and FCAS markets.

Comparative energy revenues for the first three months of 5MS for Lake Bonney BESS and an optimal energy-only battery are shown in Figure 8 and Figure 9 below.

Figure 8 Comparative Energy Revenues of Lake Bonney BESS and Optimal Energy-Only Battery

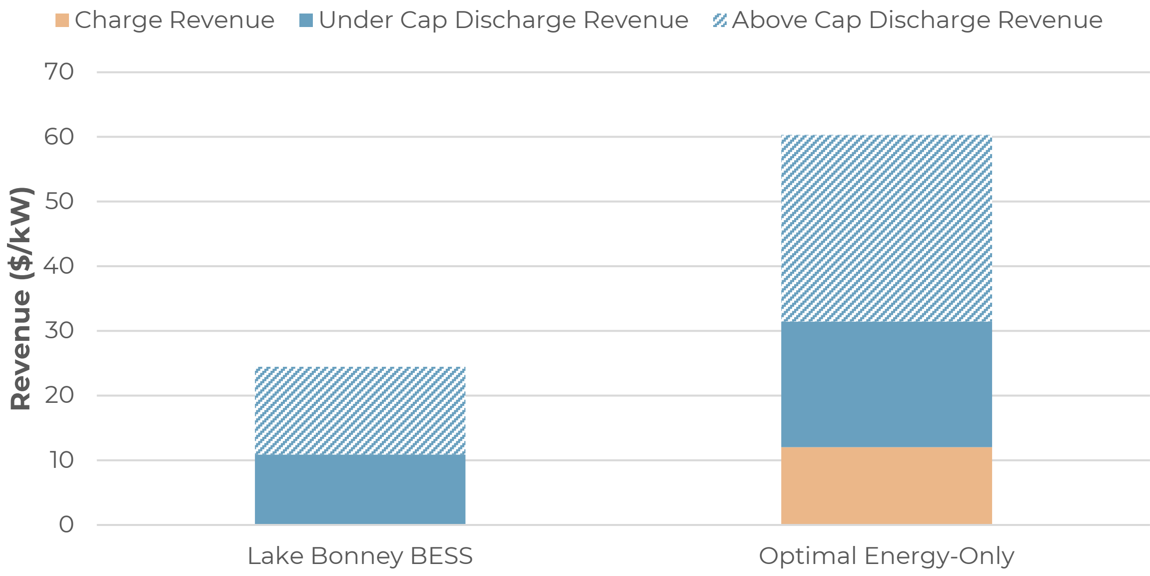
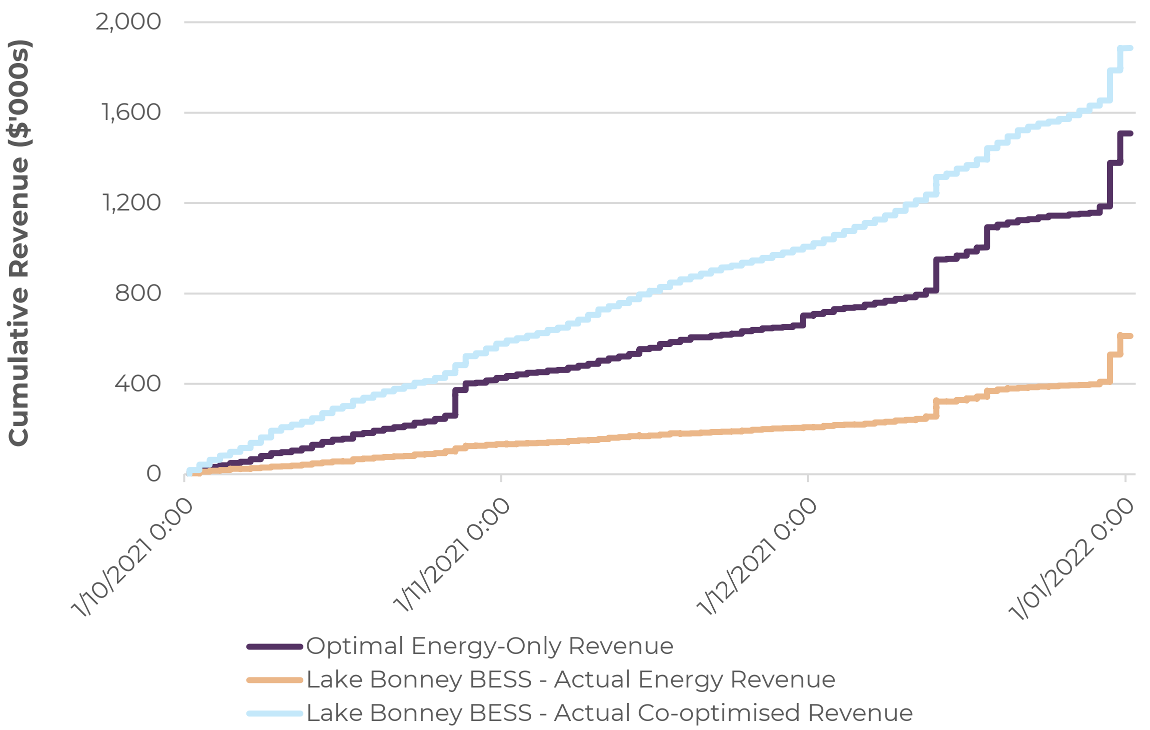


Figure 9 Total Cumulative Revenues of Lake Bonney BESS and Optimal Energy-Only Battery



From analysing the differentials between energy values shown in Figure 8 above, the following results can be observed:

Revenues achieved from charging the battery under the optimal energy-only profile (which would account for both profits when charging during negative prices and costs when charging during positive prices) accounts for nearly 20% of the total revenues earned during this period ($12.03/kW), while in the actual operation of Lake Bonney BESS the charging revenue was marginally positive at $0.12/kW.

This difference is driven from a number of factors, including:

- Difficulty in forecasting negative prices in real-time, which has been noted previously in the operations of Lake Bonney BESS.
  - This is reflected in the costs of charging at above cap (>$300/MWh) prices. While the optimal model never charged above this price, the Lake Bonney BESS was seen to charge at times during above cap prices - reflective of the difficulty of managing the battery state of charge during real time operations as potential arbitrage opportunities appear in the short-term.
- Co-optimisation of the Lake Bonney BESS leads to charging through the Lower Regulation service at times, which while incurring potentially higher charging costs in the energy market also provide revenues from enablement in this market for a higher net revenue (as reflected in Figure 9).

The difference in under-cap discharge revenue is driven by the co-optimisation targeted by Lake Bonney BESS. As mentioned above, the co-optimisation between Regulation FCAS and the energy markets for Lake Bonney BESS means it will potentially discharge into the energy market at times that the optimal energy-only model does not. However, the additional revenues earned by the BESS for enablement in Regulation FCAS during these periods means that a higher net revenue can be earned (as reflected in Figure 9).

- This is also observed when comparing the amount of discharge cycles that are incurred from energy arbitrage. For the energy-only model, this is of course 100%, while Lake Bonney BESS only attributed for 45% of its discharge cycles.

The difference in above-cap discharge revenue is mainly down to the ability to capture a small number of extreme high-prices events, seen in Figure 9 as the sharp increases for the cumulative Optimal Energy-Only revenue. However, in analysing why Lake Bonney BESS was unable to capture these events a combination of maintenance outages and high portfolio generation levels between Iberdrola's wind and gas assets could explain the reduced capture rates of these high energy prices when analysing Lake Bonney BESS as a merchant asset, and not within the wider South Australian portfolio.

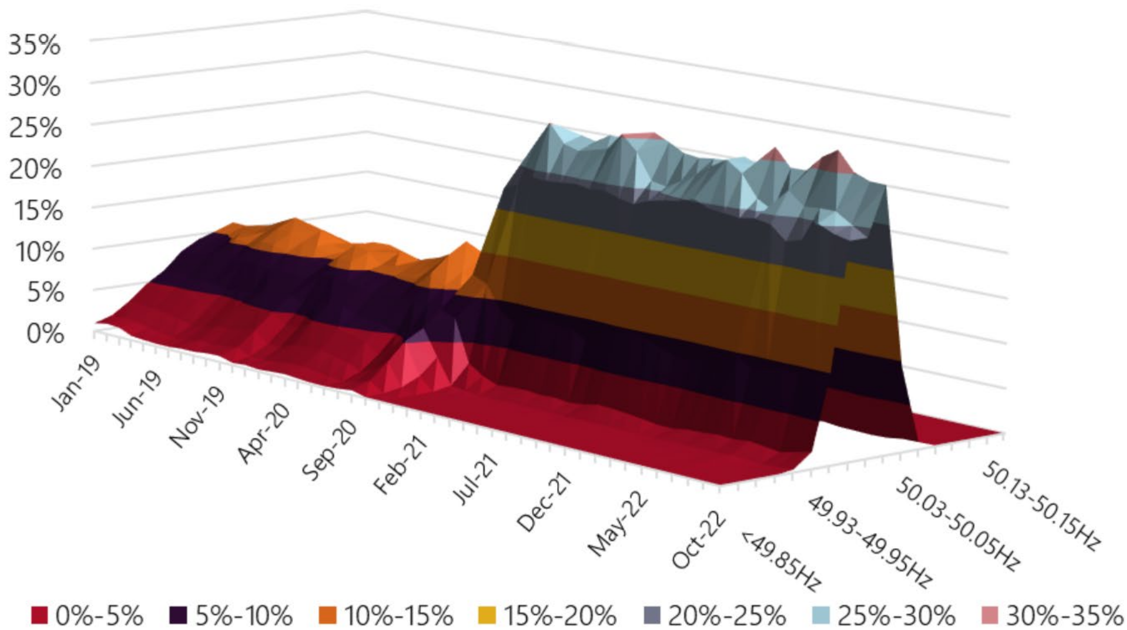
6.4 Ongoing Implementation of Causer Pays Factor Management

Implementation of Tightened Deadband

To comply with the requirements of mandatory PFR, Lake Bonney BESS considered the additional revenue opportunity of increased contingency FCAS registration values with a tightened deadband as well as the cost of increased cycling. Lake Bonney BESS was configured with a temporary deadband agreed with AEMO while the functionality of a 6-point droop was being developed by the OEM. Once implemented, the 6-point droop curve allowed the battery to respond to narrow deviations with a higher droop coefficient in order to limit the impact of additional cycling of the battery, and the agreed droop coefficient of 1.7% from a wider deadband.

The impact of mandatory PFR on the frequency distribution of the NEM is shown in Figure 10 below and is reflective of a much tighter distribution of frequency around 50Hz, with frequency sitting at the NOFB limits of 50 +/- 0.15Hz far less often.

Figure 10 Monthly Frequency Distribution Jan 2019 to Oct 2022 (Source: AEMO)



Causer Pays Factor Aggregation Methodology

To apportion the cost of providing regulation FCAS to individual generators and loads, AEMO calculates a Causer Pays Factor (**CPF**) for each market participant that represents the percentage of costs to be recovered from a participant. The CPF for scheduled and semi-scheduled units is calculated every 28 days as an aggregation of each valid 4-second interval reading of a unit's active power response. Non-scheduled generation and loads account for the remaining aggregate deviation from the linear trajectory assumed by AEMO.

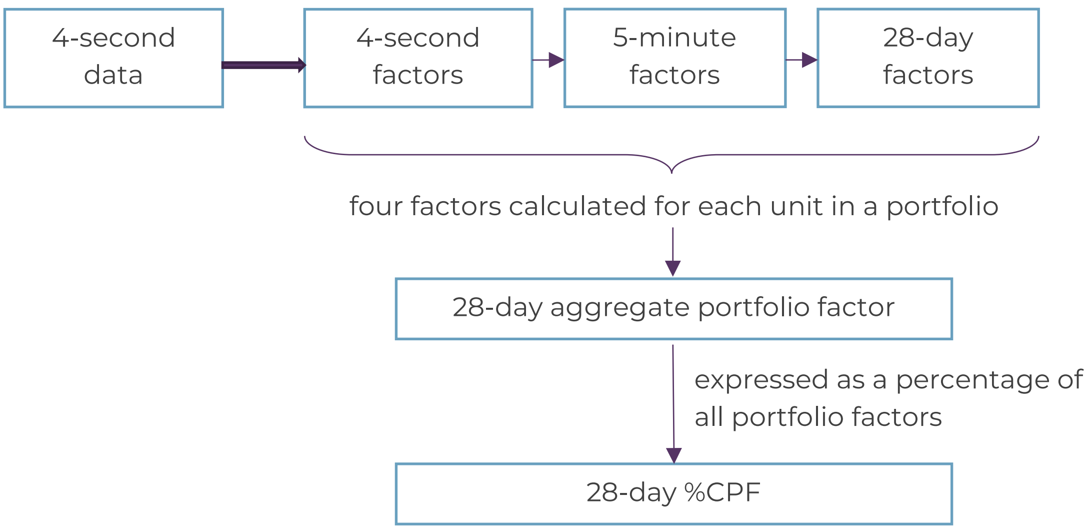
Firstly, AEMO determines the trajectory of a unit across a dispatch interval based upon its previous and current energy dispatch target, as well as 4-second enablement in regulation. Then for each 4-second interval, the active power of the unit is compared with its trajectory, and the difference is calculated. This is then multiplied with the equivalent 4-second raise or lower regulation FCAS enablement for the NEM area (mainland or Tasmania). A positive value indicates that the unit helped maintain the supply/demand balance, and a negative value indicates that the unit hindered it.

These 4-second values are filtered by correlation of regulation enablement with frequency then aggregated into 5-minute intervals to produce the four following 5-minute factors for each DUID:

1. **LNEF**: Lower regulation required and DUID **not enabled** in lower regulation
2. **RNEF**: Raise regulation required and DUID **not enabled** in raise regulation
3. **LEF**: Lower regulation required and DUID **enabled** in lower regulation
4. **REF**: Raise regulation required and DUID **enabled** in raise regulation

These factors then aggregated over the 28-day period by market participant to calculate the overall effect of each market participant on the frequency of the NEM. This aggregation process in summarised in Figure 11 below.

Figure 11 CPF aggregation methodology



Estimated Causer Pays Factor Management Impacts

Applying the above methodology to the operation of Lake Bonney throughout 2021, the accumulated LNEF and RNEF of Lake Bonney BESS and wind farm (stages 2 and 3) are shown in Figure 12 and Table 7 below.

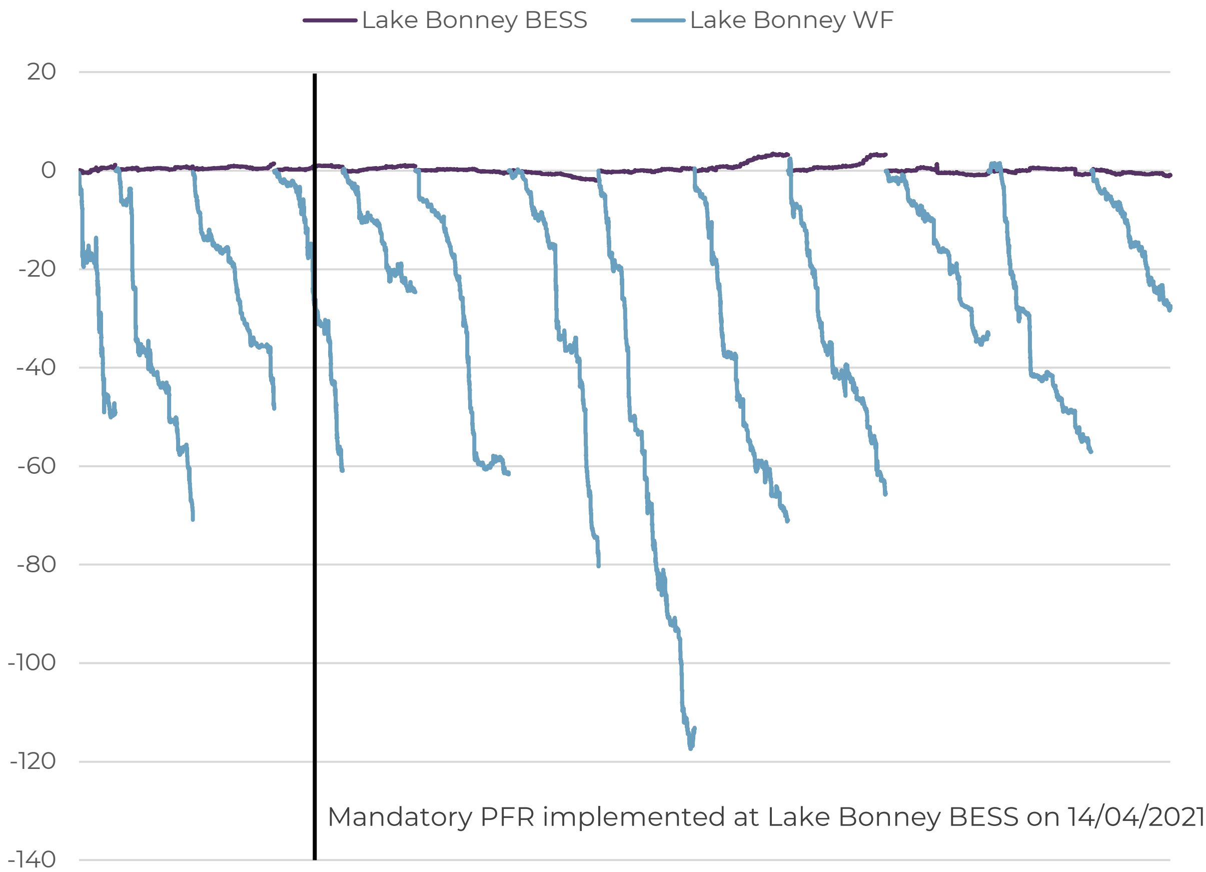
Table 7 LNEF and RNEF Factors for Lake Bonney BESS and Wind Farm Stages 2 & 3

28 Day Period	Lake Bonney BESS			Lake Bonney WFs (2 & 3)			
	LNEF	RNEF	Comb.	LNEF	RNEF	Comb.	Uplift (%)
18-01-21 to 31-01-21	0.01	1.19	1.20	-3.61	-45.52	-49.13	2.4%
31-01-21 to 28-02-21	0.19	0.71	0.90	-4.96	-65.92	-70.87	1.3%
28-02-21 to 28-03-21	0.04	1.41	1.44	7.15	-55.50	-48.35	3.0%
28-03-21 to 24-04-21	0.71	0.11	0.81	-15.85	-45.08	-60.92	1.3%
24-04-21 to 21-05-21	0.54	0.38	0.92	-1.90	-22.73	-24.63	3.7%
21-05-21 to 19-06-21	0.18	-0.52	-0.33	-9.10	-52.41	-61.51	-0.5%
19-06-21 to 17-07-21	-0.36	-1.47	-1.83	4.10	-84.13	-80.03	-2.3%
17-07-21 to 15-08-21	0.44	-0.01	0.44	-10.97	-102.16	-113.13	0.4%
15-08-21 to 12-09-21	0.68	2.54	3.22	-31.77	-39.20	-70.97	4.5%
12-09-21 to 10-10-21	0.43	2.85	3.28	-7.72	-57.89	-65.62	5.0%
10-10-21 to 07-11-21	-1.19	0.58	-0.61	-14.42	-18.90	-33.32	-1.8%
07-11-21 to 04-12-21	0.22	-0.88	-0.65	-7.19	-49.86	-57.05	-1.1%
04-12-21 to 01-01-22	-0.05	-0.89	-0.93	-5.32	-22.20	-27.51	-3.4%

As shown above, the implementation of mandatory PFR at Lake Bonney BESS did not see a large increase in positive LNEF / RNEF factors, with the largest uplift in the combined Lake Bonney Factor at 5.0% for any 28-day period. It should also be noted that for a number of 28-day periods, Lake Bonney BESS had an overall negative impact on the combined factor (5 of 13 intervals).

One of the ongoing factors that has limited Lake Bonney BESS from providing a greater influence on the combined causer pays factor is the consistent enablement of the battery in the regulation FCAS markets, which excludes the battery from earning a positive factor in these intervals. The tightened frequency distribution of the NEM has also limited the BESS from providing a larger positive factor, as there are very few intervals where the battery is providing a large, positive response where frequency has deviated far from 50Hz.

Figure 12 Aggregate Factors for Lake Bonney BESS and Wind Farm Stages 2 & 3 on 28-day basis



Ongoing Causer Pays Factor Management Outcomes

While there is some potential short-term benefit to causer pays factor management by a battery, this has not been observed to a notable level with the current configuration of Lake Bonney BESS.

From 8 June 2025, the implementation of the PFR Incentive Arrangements that will apply a double-sided causer pays mechanism will remove the above configuration of causer pays mechanism as a potential revenue stream. Instead, the double-sided causer pays mechanism will apply on a DUID basis (instead of a market participant level), so there will no longer be an opportunity to offset a different generator with a positive frequency response - although this may still be incentivised for the battery through the double-sided mechanism that will similarly reward positive responses that assist in managing frequency.

7. Project Risks and Treatments

The key risks and treatments encountered throughout the development, construction and operations phase are outlined in Table 8 below. Note that the below project risks do not include general safety considerations that should be accounted for on any construction site / operational electrical assets, and instead focus on specific risks for Lake Bonney BESS.

Table 8 Project Risks and Treatments

Risk	Treatment
Development	
Project revenues	Greater certainty on project revenues during the development stage was created by: — Consideration of the BESS as part of the wider SA portfolio, so that its potential revenue outcomes were not considered in isolation — Ensuring that the procured system would be capable of participation across all existing markets and potential future markets — Contracting an autobidding system to assist in the dispatch of the BESS in the NEM once operational
Appropriate system warranties / guarantees	Ensuring the contracted performance of the BESS (including energy retention) via: — Contracting strategy utilising a wrapped EPC structure, so that guarantees were provided at the point of connection and with only one counterparty — Accounting for the warranty provisions of the EPC contract within the operational regime of the BESS to maintain these performance guarantees
Grid connection – modelling works	In retrospect, the risks posed by the modelling works required to receive an offer to connect were not fully anticipated (with difficulties noted as lessons learnt in the following section). Processes to mitigate these issues in future would include: — Detailed understanding of capabilities of existing asset simulation models and all potential integration risks — Increased time allowances for iterative grid modelling — Assessing model compliance of OEMs and their previous experience in securing NEM connections

Risk	Treatment
Grid connection – physical works	Further difficulties in establishing the contracts for the physical connection works were posed by the grid modelling issues, and partly managed through: — Progression of site works under preliminary works agreement to maintain schedule with other construction activities — Utilising the existing construction workforce on site to undertake earthworks and free-issue to ElectraNet
Construction	
Existing underground services	Earlier identification of existing underground services would have removed the risk on the project construction timeline of the required re-positioning works, as detailed in the following lesson learnt: Lesson learnt: Management of existing underground services
Management of existing wind farm operations	Management of existing wind farm operations through: — Detailed consideration of site design, particularly road interface points within the wind farm site — Coordination of vehicle movements, specifically during periods of BESS component delivery or scheduled wind turbine maintenance
Coordinated plant outages	The coordinated outage of the Mayurra substation was managed due to the extended delays in the grid connection works on site. However, allowances in the project were made for: — Consideration of the coordinated outage in the initial project timeline — Consideration of the cost of lost production during a shut if it was not coordinated with the wind farm

Risk	Treatment
Operations	
Revenue achievement	Ensuring that the maximum revenues available to the BESS were achieved was managed by: — Integration of bidding strategy between the automated system and human intervention in periods of market volatility, utilising a least-regrets operating strategy — Developing algorithms to monitor the performance of the Lake Bonney BESS against an ideal battery, to see how Autobidder setting changes influenced revenue outcomes — Continual improvements to forecasting of potential volatility events, including monitoring weather systems that will impact SA's rooftop solar production
Unanticipated technical challenges	A number of unidentified risks to the performance of the Lake Bonney BESS in operations where encountered, including: — AGC availability issues (removing the ability to participate in the regulation FCAS markets for the effected dispatch intervals) — FCAS trapezium stranding (removing the ability to dispatch into the FCAS markets in the next dispatch interval), which was resolved through discussions with ElectraNet and AEMO to implement a data recording fix
IT system functionality	The operation of Lake Bonney BESS is highly contingent on the performance of out IT systems, both for bidding systems and compliance monitoring. Iberdrola Australia's IT resources continually monitor all of our operational assets to ensure security and availability is assured.

8. Project Lessons Learnt

A record of all of the lessons learnt and recommendations across the Lake Bonney BESS project is provided below, across the three main phases of the project: development, construction and operations.

8.1 Development Phase

Detailed Design Considerations

Lesson learnt: Lake Bonney BESS site selection

A major consideration that was overlooked in the site selection of the Lake Bonney BESS during this period was the system strength of the grid at the LBWF point of connection. When the original connection enquiry for the Lake Bonney BESS was undertaken, it indicated that there was a shortfall in system strength in the area and a Full System Strength Impact Assessment (**FSSIA**) may be required. The impact that the FSSIA would have on the project timeline was underestimated at the time with the process and modelling capabilities to fulfil the assessment not fully understood, only coming into practice in July 2018.

While these delays did not add significant capital costs, they did prevent the project from generating revenue because of the late achievement of commercial operation.

While the suitability of Lake Bonney as the project site could be debated now, Iberdrola Australia believes that securing a grid connection has become the single biggest risk for most generation projects in the past two years.

Developing frameworks for efficiently procuring system strength ahead of time, before unanticipated shortfalls occur, should therefore be a NEM priority in order to avoid future delays and/or curtailment of critical infrastructure.

Lesson learnt: Comparison of energy storage system parameters

A key takeaway from comparing the different technical capabilities of proposed systems was that there was little cohesiveness in how the parameters of batteries are reported, even between different Li-ion proposals. This required Iberdrola Australia to exercise diligence in assessing each proposal so that the correct information was passed through to properly value each proposal.

Typical discrepancies in parameters were around:

Energy cycle definition (and cycling allowance) – these definitions play an important role in defining how much energy throughput is allowed in the battery warranty to ensure that the energy storage capacity does not degrade more than expected. Some offers defined cycles as moving between two different state of charge (**SoC**) points, while others only considered cycling through the energy markets (and not intermittent cycling through regulation services).

Energy storage capacity – it is important to clarify if the stated energy storage capacity includes any depth of discharge (**DoD**) allowance to ensure that the usable energy storage capacity is understood.

Measurement point of parameters – For all parameters provided for battery systems, the point of measurement for these parameters need to be stated. Typical points of connection include at the low-voltage AC terminals of an inverter or at the grid point of connection. Losses between the low-voltage AC terminals and the asset's connection point need to factor in the balance of plant losses to fully understand the impact this will have on the project.

Lesson learnt: Allowances for progression in battery design

The original submission for development approval for the Lake Bonney BESS was made under the assumption that the preliminary dimensions of the site and layout of equipment would not change, given that typical allowances for things such as micro-siting of wind turbines would not apply to a BESS.

However, it was seen that design optimisation could alter the layout of the dimensions of the project site and cause the need for a variation to the development plan consent. While there is minimal risk in the variation process (so long as the change in project layout is minor), it would not have been required if a more conservative layout was used for the development application in the initial submission.

Business Case Considerations

Lesson learnt: Battery revenue modelling

Iberdrola Australia has invested significant time into developing models that emulate the dispatch of a battery in the NEM. These models are built as Linear Programs (**LPs**) which incorporate the constraints of co-optimised dispatch across the energy and FCAS spot markets, along with the technical constraints of the battery's physical capabilities (e.g. maximum power capacity, energy storage capacity, etc). LPs are chosen to model the battery as they are able to replicate the inter-temporal relationship between key variables such as state of charge, as well as being able to handle the constraints relating to the bidding capacity of a battery.

These LPs are currently used to both assess how the Lake Bonney BESS is operating in the NEM by how effectively it is earning revenue based on market conditions (looking back at actual prices), and to value new battery opportunities across the NEM (using forecasted price traces).

However, as noted above, the model is only as good as the price forecasts that are used as inputs (garbage in means garbage out). This makes long-term battery valuations difficult to produce, no matter how well an LP model reflects the operation of a battery in the NEM.

Lesson learnt: Importance of considering the Lake Bonney BESS as part of Iberdrola Australia's portfolio

A portion of revenue attributed to the Lake Bonney BESS business case during the first few years of operation was to provide regulation FCAS during periods when 35MW of regulation services were required to be procured locally from the SA region of the NEM. These events had historically led to high average regulation FCAS prices which were partially reimbursed by LBWF through the CPF methodology.

In October 2018, this 35MW constraint was removed by AEMO. For a stand-alone battery project, this would have lowered its overall revenue potential as the removal of the constraint reduced the likelihood of high-priced events. However, from the view of Iberdrola Australia's portfolio, the removal of this constraint would also see a significant reduction in LBWF's reimbursement of regulation FCAS costs.

It is important to consider the value of the Lake Bonney BESS as a physical hedge against FCAS prices for the wider Iberdrola Australia portfolio, with either the Lake

Bonney BESS earning revenues in the FCAS markets or LBWF (and/or the wider Iberdrola Australia asset portfolio) having lower FCAS operating costs.

Despite long-term revenue uncertainty, the NEM market design allowed for investment in new firming capacity once appropriate consideration of all revenue streams and portfolio benefits was made.

Recommendation: Further clarification from AEMO on droop settings for large-scale batteries

Further clarification on the registerable capacities of batteries in the contingency FCAS markets would provide greater certainty over the potential revenue available to a project, and the potential capacity that could be registered into the contingency FCAS markets.

Current advice from AEMO states that:

> *Unless an alternative droop limit is specified by AEMO, the minimum allowable droop setting of any BESS is 1.7%, regardless of its capacity.*[2]

However, there is no discussion around what circumstances an alternative droop limit will be specified or allowed. In restricting the droop setting of batteries to 1.7%, AEMO is not harnessing the full potential of those assets.

In parallel with these changes, there would also be value in developing explicit services for the procurement and activation of the very fast responses available from batteries.

[2] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Ancillary_Services/Battery-Energy-Storage-System-requirements-for-contingency-FCAS-registration.pdf

Grid Connection Considerations

Lesson learnt: Impact of delays in executing TCA

ElectraNet's requirement to have an executed TCA in order to undertake works on site was not fully understood during the project development stage, nor reflected in the scheduling of construction activities.

Clearer understandings of the scopes and pre-conditions to be contemplated under each agreement will be pursued in future projects, particularly if there is a risk that construction works are required under the TCA prior to when the GPS and FSSIA are forecasted to be finalised. Further integration of grid modelling activities into the project schedule should also acknowledge the dependencies between the construction and modelling work streams.

Recommendation: Clarifications on Applicant responsibilities in the FSSIA process

The responsibilities of the Applicant under the FSSIA process should be clearly defined, as it is unclear what the course of action would have been in a scenario where LBWF was owned by a separate entity, or if Iberdrola Australia could not engage the OEMs of LBWF to provide updated models that were compatible with both the state-wide and site-specific Lake Bonney BESS PSCAD models.

We believe that it should not be the responsibility of an Applicant undergoing the FSSIA to solve integration issues caused by third-party models. In any event, the work currently undertaken by AEMO to provide remote access to the overall system model should greatly simplify this process and alleviate some of the issues that were encountered on this project.

Recommendation: Further engagement on the FSSIA process

The experience of the FSSIA process at Lake Bonney could deter further investment in BESS projects at brownfield development sites and could have the perverse impact of preventing the implementation of BESS projects where they can be deployed most effectively. Indeed, existing sites are probably easier to retrofit and facilitate the addition of batteries, but the risk associated with nearby generators or the risk of reopening an existing generator's GPS could be a barrier to investment.

Recommendation: ESCOSA licence timing considerations for large-scale battery projects

While the ESCOSA licence did not delay the project energisation due to difficulties in other project areas, further flexibility could be included into the ESCOSA licencing process for future battery projects due to their shorter time period from the finalisation of pre-requisite agreements to targeted energisation compared to large-scale wind or solar farms.

8.2 Construction Phase

Lesson learnt: Management of existing underground services

Based on the experience during the Lake Bonney BESS, a proactive response to identifying underground services should be employed in any future projects. This would include the undertaking of exploratory works in the vicinity of the substation extension area during the development phase of the project to identify all of the services that would require relocation if the project were to proceed. It would also allow time to contract these works and align them with the wider project schedule.

Greater communication with the site manager and technicians would also be encouraged to ensure that the most up to date information and drawings are being used for the project.

8.3 Operations Phase

Market Opportunities

Lesson learnt: Potential value of 5-minute settlement

The difficulties discussed above, of uncertainty in trading interval energy prices due to variations in dispatch interval prices, will be removed once energy prices are settled on a dispatch interval basis. This should present further arbitrage opportunities to batteries, by giving clearer price signals while also increasing price volatility with dispatch interval prices no longer averaged out over a trading interval.

However, it is important to consider that the following may erode some of this value:
- Participants are likely to alter their bidding behaviour once settlements occur on a dispatch interval timeframe;
- If the battery was to miss out on a single dispatch interval price spike, it would be unable to capture this value in the remainder of the trading interval; and
- The above is also true for when energy and FCAS prices spike concurrently.

Lesson learnt: Comparative value of 5MS for different hours of storage

With a higher amount of storage available, the 4 hour system does not benefit from the additional flexibility that 5MS allows for, as if the high-price period lasts for less than 4 continuous hours, the battery can simply discharge throughout this entire event.

It is important to note that as the need for longer duration storage within the NEM becomes greater with increasing amounts of renewable generation, the potential benefits of 5MS may have a limited impact on the economics of a longer duration storage asset.

Lesson learnt: 5MS opportunities for battery storage

Iberdrola Australia continue to monitor the dynamics of the energy market as participant behaviour under the new 5MS regime develops. As the assessment above only considers the price dynamics of a single year in a single region of the NEM where 5MS was implemented for a portion of this year, the potential benefits of 5MS on the economics of a battery system require further analysis and investigation into the future.

Market Events

Lesson learnt: Configuration of BESS during frequency excursion events

Prior to the separation event, Iberdrola Australia was unaware of the requirement to freeze the AGC setpoint when frequency goes outside the NOFB. It was only after discussing the performance of the system during that event that Iberdrola Australia became aware of different logic being implemented on other assets.

This issue was then raised with AEMO to ensure that the BESS was adequately configured. After careful consideration, AEMO advised that the preferred configuration for the Lake Bonney BESS was to freeze its AGC signal's setpoint whenever frequency is outside the NOFB.

As a highly configurable and flexible system, further collaboration and knowledge sharing is welcomed, to improve how the BESS can improve its performance during power system events.

Lesson learnt: Utilisation of a BESS during a SA islanding event

The 31st January separation event indicated how AEMO will likely look to utilise utility-scale battery systems in islanded regions of the NEM in the future, by constraining the operation of each BESS in the energy and regulation FCAS markets such that they are focussed on reserving both power and energy storage capacity for the provision of contingency FCAS.

The impact of these constraints on Iberdrola Australia's SA generation and customer portfolios are discussed below.

Lesson learnt: Inability to physically hedge CPF exposure through market participation

The 31st January separation event highlighted that the Lake Bonney BESS would not always be available to hedge the exposure of the Lake Bonney market participant's CPF through active participation in the regulation FCAS markets.

Instead, the CPF exposure could be managed as it is calculated, by configuring the BESS as discussed in Section 6.2 above. This would ensure that the CPF is minimised prior to the time that it has market exposure, where it may or may not be able to be hedged by the BESS.

Recommendation: Utilisation of a BESS during a SA islanding event

While the focus on reserving contingency FCAS capabilities during the unusual islanding event was reasonable and helped AEMO maintain system security, Lake Bonney BESS, and battery energy storage systems in general, are capable of providing high-quality regulation FCAS to stabilise system frequency to the benefit of the islanded region.

Iberdrola Australia would welcome further collaboration with AEMO on the most effective utilisation of utility-scale storage assets when a region is islanded, including the potential for increased BESS participation in the regulation FCAS markets and optimising the energy storage reserves in the event that a contingency FCAS response is required.

Iberdrola Australia believes that optimal limits on energy storage reserves should be adequately selected for each BESS depending on what event AEMO is protecting against (e.g. a 1-hour excursion from NOFB) as opposed to being arbitrarily imposed as a SOC range (e.g. 30%-70%) for all BESS, each with different ratings and storage capacities.

Lesson learnt: Increased monitoring of localised weather conditions

As distributed PV continues to increase its influence on the operational demand of the SA region, effective monitoring of the localised weather conditions in Adelaide where these distributed PV systems are concentrated becomes increasingly critical to managing potential price volatility.

While AEMO provides forecasts of operational demand that accounts for the predicted output of distributed PV generation, integrating additional means of identifying when these conditions may occur will allow Iberdrola Australia to better utilise its firming assets and provide cover to its customer portfolio when any of its monitoring methods indicate that market volatility may occur due to the above conditions.

Iberdrola Australia closely monitors this risk through the following methods:

1. Utilisation of AEMO's forecasts for scheduled demand;
2. Continual communications with the SA Gas Turbines operations team located in greater Adelaide for real-time weather condition updates; and
3. Integrated satellite monitoring of cloud cover within the Operational Control Centre.

Non-Market Opportunities and Issues

Lesson learnt: Commercial value of CPF management

While there are a number of market factors that determine the overall value of managing the CPF of a market participant, Iberdrola Australia is well placed to assess these shifting dynamics with the CPF model it validated during this trial.

Lake Bonney BESS is a highly flexible asset that can take advantage of changing market dynamics to continue to maximise its value within the Iberdrola Australia portfolio.

Lesson learnt: Stranding outside of FCAS trapeziums

The identified stranding issue has been a previously unconsidered technical risk for battery systems by Iberdrola Australia that has a commercial impact on the value of the asset. Although this issue could occur for any FCAS provider, the risk is thought to be greatest for battery systems due to the amount of time that they operate at their rated capacity while also providing regulation or contingency FCAS.

Iberdrola Australia is currently investigating potential fixes to this issue in collaboration with Tesla, AEMO and ElectraNet.

Lesson learnt: Continued importance of IT telemetry for BESS operations

Iberdrola Australia continue to maintain and monitor a number of IT systems responsible for ingesting, receiving and transferring telemetry data required for the formulation, receipt and submission of timely bid offers.

Continual improvements to these systems to ensure that submission timelines are achieved with minimal downtime are necessary to ensure that the battery is bid into the market with the most up-to-date information possible.

Operational Strategies

Lesson learnt: Value of a human operator

Although an optimal bidding strategy for Lake Bonney BESS is generated through Tesla's AutoBidder software, Iberdrola Australia does not rely solely on AutoBidder to determine how the BESS is bid and dispatched/enabled in the NEM.

A key reason for this is the value of a human operator being able to interpret the price signals seen in AEMO's pre-dispatch prices (which the AutoBidder relies upon to optimise its bidding strategy) and assess the probabilistic outcome of those prices being realised.

A human operator is also well placed to make 'least regret' decisions, such as the event described above. The potential downside in conserving the BESS' state of charge and potentially missing out on a $379/MWh energy price is minimal compared to the potential upside of capturing an energy price at $14,700/MWh.

Lesson learnt: Value of a diversified portfolio

The 31st January separation event demonstrated the value of a diversified portfolio in the SA region of the NEM. Access to revenue opportunities across the nine spot markets helped to mitigate the risk of curtailment, either for the LBWF stages in the energy market or the constraints on Lake Bonney BESS limiting participation in the regulation FCAS markets.

However, the co-location of these plants still poses the risk that all of the Lake Bonney assets could be constrained off during a particular event. Iberdrola Australia's investment in the SA Gas Turbines, which will be located in a different part of the network, will reduce the impact of this risk on the SA customer portfolio.

Lesson learnt: Continual improvement to bidding strategies

Under 5-minute settlement rules, it has become increasingly important to ensure that high Energy prices are captured within each dispatch interval as the increased arbitrage opportunities are no longer averaged out over a full 30-minute trading interval.

To ensure that the maximum value of Energy market volatility can be captured by the Lake Bonney BESS, continual improvements have been made to the bidding strategies managed by the Operational Control Centre.

These improvements include implementing strategies with standing bid offers in the energy market to ensure the battery is available in this market under AEMO's dispatch engine co-optimisation process.

9. Addendum

9.1 Financial Performance

A comparison between the forecasted revenues of Lake Bonney BESS in the Financial Model provided to ARENA in September 2018 and the actual revenues earned in the first two years of operation is provided in Table 9 below.

Table 9 Comparison of financial performance

Modelled Revenues ($000s)	Year 1	Year 2	Total
Energy Arbitrage	775	1,020	1,795
Regulation FCAS	1,909	2,073	3,982
Contingency FCAS	860	1,701	2,561
Other Revenue	200	200	400
Total	**3,743**	**4,995**	**8,738**

Actual Revenues ($000s)	Year 1	Year 2	Total
Energy Arbitrage	783	2,053	2,836
Regulation FCAS	3,420	3,541	6,962
Contingency FCAS	8,057	2,522	10,580
Other Revenue	0	0	0
Total	**12,261**	**8,116**	**20,377**

Difference ($000s)	Year 1	Year 2	Total
Energy Arbitrage	8	1,032	1,041
Regulation FCAS	1,511	1,468	2,980
Contingency FCAS	7,198	821	8,019
Other Revenue	-200	-200	-400
Total	**8,517**	**3,122**	**11,639**

As discussed throughout previous operational reports, the financial performance of Lake Bonney BESS has been well above expectations and periods of extreme market volatility have led to large increases in expected revenue. This is most notable in the Year 1 contingency FCAS revenues, where the January 31st separation event led to a large amount of revenue earned in the month of February alone.

Also of note is the discrepancies in the Other Revenue earned by Lake Bonney BESS, which were modelled to be achieved through causer pays factor improvements. While our Causer Pays Factor trial was able to demonstrate the BESS could reduce the exposure of the wind farm, the associated revenues saved through this approach have not been monitored on an ongoing basis. This is due to a tightened deadband being required for primary frequency response, while also allowing for an increased contingency FCAS capacity to be registered, with Causer Pays benefits now a by-product of this business as usual approach.