Infigen

Lake Bonney BESS

Project Summary Report

September 2020

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Executive Summary

This report provides a project summary of the Lake Bonney BESS in the development, construction and commissioning phases. The Lake Bonney BESS is a 25MW / 52MWh energy storage system that utilises Tesla's Powerpack battery technology and was installed alongside Infigen's operational Lake Bonney wind farms that have a combined capacity of 278.5MW.

Development

While Infigen had been exploring the possibility of constructing a BESS in South Australia since 2015, the combination of market, portfolio and funding opportunities in 2018 meant that a business case for a BESS could be made.

The location chosen for the construction of the BESS was Infigen's operational Lake Bonney wind farm, so that the existing site and grid connection infrastructure could be utilised. Co-location of the assets also offered the potential to reduce curtailed energy losses and manage the wind farm's causer pays factor but required the BESS to be connected into a 'weak' area of the grid.

Tesla was selected as the preferred battery equipment supplier due to their use of lithium-ion battery technology, previous project delivery experience in South Australia, cost-competitiveness and the ability to earn market revenues using Tesla's AutoBidder software. System sizing was determined by considering a number of factors, including capital costs, existing transformer capacity at Lake Bonney, and the hours of storage required to effectively participate in each market.

The development application process for the Lake Bonney BESS was straight-forward, given the existing nature of the proposed site. A single modification was required to the original development plan consent due to an optimisation of the site dimensions following detailed design.

Contracting and Procurement

Contracting the delivery of the BESS with Tesla was initiated through an early works agreement that sought to finalise procurement timelines for battery and inverter equipment and allow for detailed design and grid studies to be progressed while the EPC contract was negotiated. An EPC contract structure was preferred due to the simplification of measuring all performance and availability guarantees at the point of connection, and a reduced interface risk during construction.

ElectraNet proceeded with the substation extension works under a MPWA, while the TCA was being negotiated.

There were no time delays incurred in the procurement of long lead items during construction. However, the battery Powerpacks had to be delivered in two separate stages due to competing priorities at the Tesla Giga Factory.

A number of contracts were also executed to manage the operational activities of the BESS, including the OEM services agreement, BoP services agreement, AutoBidder services agreement and the HV switching contract.

Construction and Commissioning

Construction works under the EPC contract were completed on schedule, with no major issues faced on site. Minor difficulties arose due to the brownfield nature of the site, including managing existing infrastructure, spacing constraints and outage alignments. Some delays in the physical connection works were experienced due to the interface between the EPC and MPWA contracts. However, this did not in itself impact the energisation date as this was significantly delayed by the connection studies (GPS & FSSIA) and subsequent execution of the TCA.

Once energised, the commissioning of the Lake Bonney BESS was completed without any notable incidents. The outcomes of both the hold point testing required by AEMO to validate the GPS, and the performance testing of the BESS required to demonstrate the technical capabilities of the system, were successful.

Grid Connection

The delay to energise the Lake Bonney BESS was due to the difficulties faced throughout the grid connection process. A number of updates and correction, for both the PSSe and PSCAD models, were required to resolve model non-compliances and issues identified by AEMO and ElectraNet. For the FSSIA to begin the models had to be largely agreed and the GPS negotiations significantly advanced, to ensure that the models would not change again.

The project was faced with numerous difficulties at various stages of the GPS negotiations. Key issues included the difficulties of strictly meeting the automatic access standard for reactive capability, the minimum SCR that the model should be tuned for to demonstrate compliance and capability, and the subjective interpretation of modelling results against the performance standards as either real issues or modelling artefacts.

The greatest challenge of the FSSIA faced by the project was the lack of visibility and control throughout the process. Integration issues between the site-specific PSCAD model and the SA system model required Infigen to engage the SA system model developer to investigate the root causes. One of the issues included the Lake Bonney wind farm model, which Infigen was fortunate to also be the owner of, as it remains unclear what procedure could have been adopted to have a third party update an identified model issue within a timeframe acceptable for the project.

Completion of the first FSSIA allowed Lake Bonney BESS to energise but required temporary site constraint to be implemented and also required a second FSSIA to be completed once the wind farm model had been updated. This highlighted a significant risk of deploying a new generator on a brownfield site, which could lead to identification of modelling or theoretical issues on an existing asset. The second FSSIA however showed that the Lake Bonney BESS did not have an adverse system strength impact.

Lessons Learnt and Recommendations

A number of lessons learnt and recommendations were identified and made during the development, construction and commissioning phases of the Lake Bonney BESS project. Those are discussed in this report, and are as follows:

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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 Pays Factor
CPP	Consolidated Power Projects Australia Pty Ltd
DC	Direct Current
DoD	Depth of Discharge
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(s)

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)
PoE	Probability of Exceedance
PSCAD	Power Systems Computer Aided Design
PSSE	Power Systems Simulator for Engineering
pu	per unit
RTF	Renewable Technology Fund (South Australia grant program)
SCAP	State Commission Assessment Panel (of South Australia)
SCR	Short Circuit Ratio
SoC	State of Charge
TCA	Transmission Connection Agreement

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1. Purpose and Distribution

1.1 Purpose of Document

This document covers the development, construction and commissioning phases 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 development, construction and commissioning learnings of the project, including:

— An overview of the project including performance overview and technical characteristics including functional description;
— Project development activities, risks and learnings;
— Procurement challenges, risks and learnings;
— Construction and commissioning activities, risks and learnings; and
— Grid connection issues, challenges and recommendations;

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

The Report represents the first reporting deliverable under the Knowledge Sharing Plan that forms part of the funding agreement between Infigen Energy and ARENA. All documentation associated with the Knowledge Sharing Plan for the Project will be available from Infigen's dedicated Lake Bonney BESS knowledge sharing portal.

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	This report
Industry Presentation on Project Summary Report	Q2 CY2020
Project Web Portal	Publicly available
Operational Report #1	Q3 CY2020
Industry Presentation on Operational Report #1	Q3 CY2020
Operational Report #2	Q1 CY2021
Industry Presentation on Operational Report #2	Q1 CY2021
Operational Report #3	Q3 CY2021
Operational Report #4	Q1 CY2022

3. Project Introduction

3.1 Infigen Energy

3.1.1 Our Strategy

We generate and source renewable energy

We generate renewable energy from our fleet of owned wind farms. With a total of 670MW of 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.

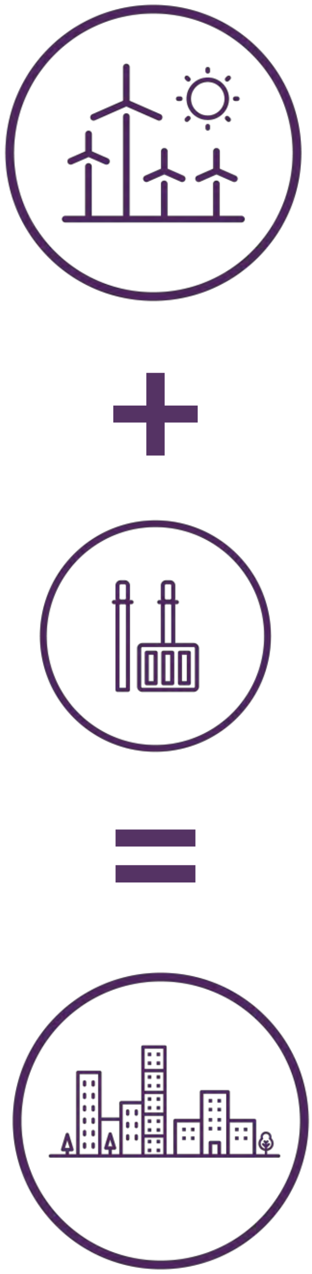
Our firming portfolio comprises Smithfield OCGT, a 123MW gas peaking plant in NSW, the Lake Bonney Battery Energy Storage System, a 25MW/52MWh battery in SA, and the South Australia Gas Turbines, 120MW of dual-fuel peaking capacity in SA.

Firming assets operate with very low levels of utilisation (sometimes as low as 2%) and because they are used to manage intermittency risk, Infigen'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'



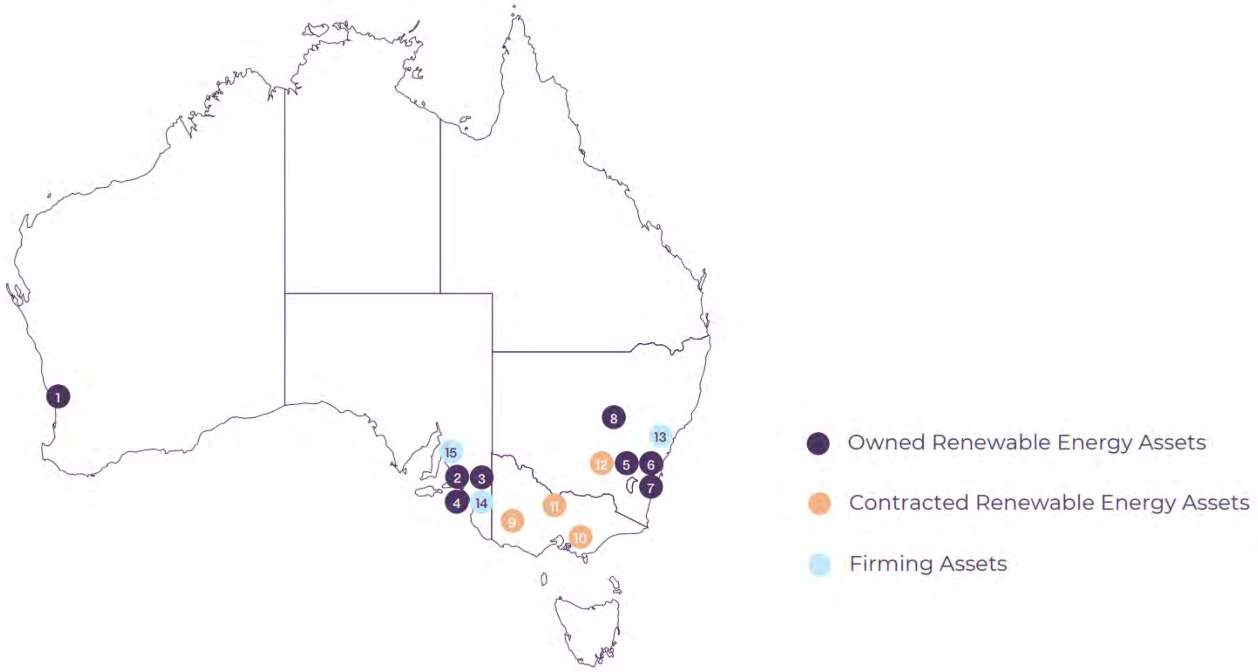
3.1.2 Our Assets

Asset		Nameplate Capacity (MW)	State	
Owned Renewable Energy Assets				**Commercial Operation Date**
1	Alinta Wind Farm	89.1	WA	Jul 2006
2	Lake Bonney 1 Wind Farm	80.5	SA	Mar 2005
3	Lake Bonney 2 Wind Farm	159.0	SA	Sept 2008
4	Lake Bonney 3 Wind Farm	39.0	SA	Jul 2010
5	Capital Wind Farm	140.7	NSW	Jan 2010
6	Capital East Solar Farm	0.1	NSW	Sept 2013
7	Woodlawn Wind Farm	48.3	NSW	Oct 2011
8	Bodangora Wind Farm	113.2	NSW	Feb 2019
Contracted Renewable Energy Assets				**Contract Start Date**
9	Kiata Wind Farm	31.1	VIC	Sept 2018
10	Toora Wind Farm	21.0	VIC	Jan 2020
11	Cherry Tree Wind Farm	57.6	VIC	Jul 2020
12	Collector Wind Farm	136.0*	NSW	Expected H1FY21
Total Renewable Energy Assets		**915.6**		
Firming Assets				**Acquisition/Commercial Operation Date**
13	Smithfield OCGT	123.0	NSW	Acquired May 2019
14	Lake Bonney BESS	25MW/52MWh	SA	Dec 2019
15	South Australian Gas Turbines	120.0	SA	Expected Q1 FY21

*Infigen contracts 60% of the output of the 227MW Collector Wind Farm

The location of Infigen's assets (aligning with the asset numbers used in the table above) are shown in Figure 1 below.

Figure 1 Infigen Energy asset location map



3.2 Lake Bonney Wind Farm

The Lake Bonney Wind Farms (**LBWF**) are located on the Woakwine Range, about 2 km from the eastern shore of Lake Bonney, near Millicent in South Australia. The wind farm was constructed in three separate stages (Lake Bonney 1, 2 and 3) with the first stage commencing operations in March 2005 and the final stage commencing operations in July 2010.

The 278.5 MW wind farm comprises 112 wind turbines across more than 22-square kilometers, which include 46 Vestas V66 wind turbines and 66 Vestas V90 wind turbines. The wind farm generates enough renewable energy to power approximately 131,700 homes each year.

Infigen has spent about $700 million on the three stages of the project, with roughly half of that investment going into Australian goods and services.

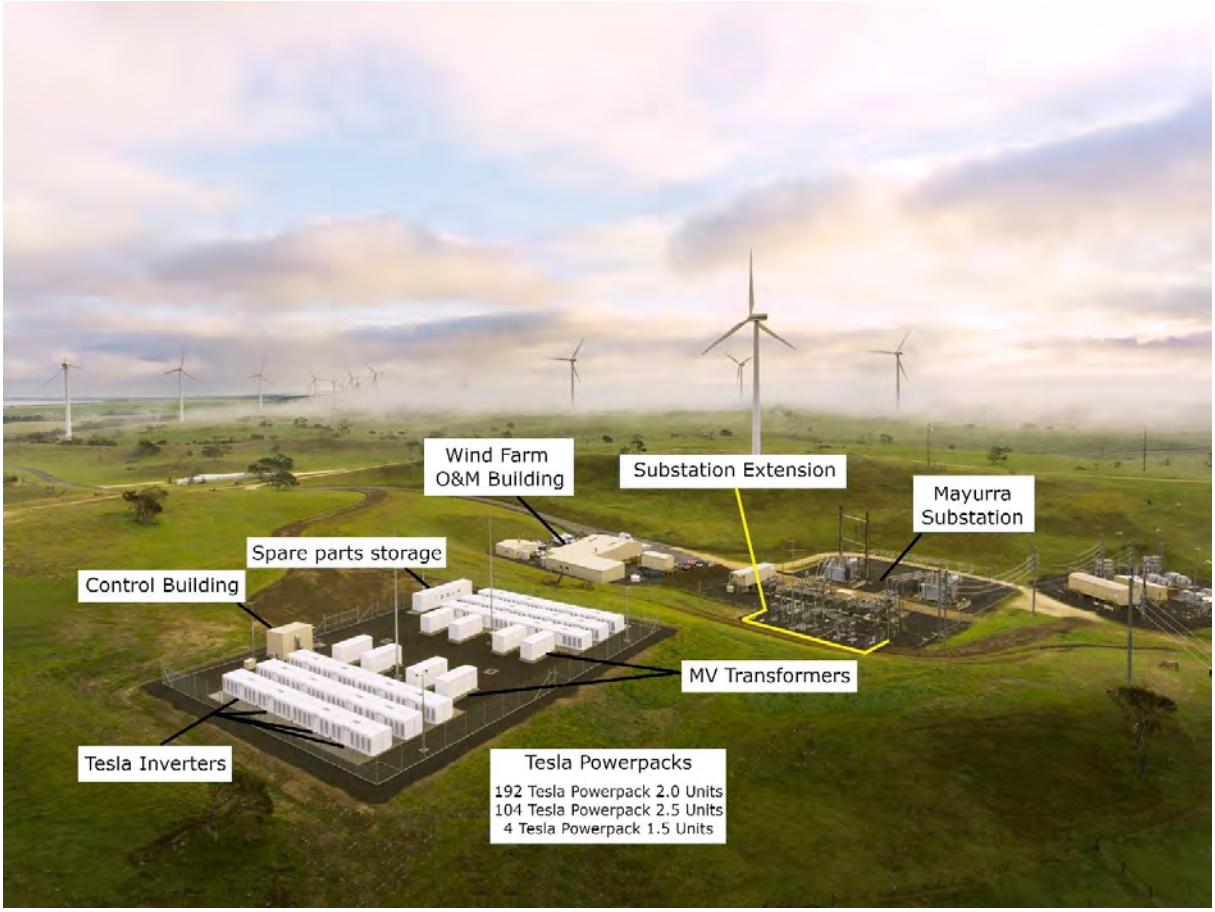
Infigen employed about 200 people over the six years of construction to build the three stages of the wind farm. In addition, Infigen with its service and maintenance provider (Vestas) currently employ 20 people directly at the site, as well as 25 local contractors and part-time workers.

Figure 2 Lake Bonney Wind Farms

3.3 Lake Bonney BESS

The Lake Bonney BESS is a 25MW / 52MWh energy storage system that utilises Tesla's Powerpack battery technology. Lake Bonney BESS was installed on Infigen's operational Lake Bonney wind farms as a brownfield development. Lake Bonney BESS. An overview of the completed Lake Bonney BESS is shown in Figure 3 below.

Figure 3 Lake Bonney BESS site overview



3.3.1 Key Project Objectives

During the development stage of the project, the key project objectives of the Lake Bonney BESS were to allow Infigen to:

— firm up Infigen's generation capacity from LBWF to increase Infigen'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.

3.3.2 Project Scope of Works

The Lake Bonney BESS project was delivered under an Engineering, Procurement and Construction (**EPC**) contract with Tesla Motors Australia Pty Ltd (**Tesla**), with Consolidated Power Projects (**CPP**) acting as the principal subcontractor. The major works completed under this contract are listed in Table 2 below.

Table 2 Scope of work under the EPC contract

Works section	List of key work items
Site Mobilisation	- Site surveying - Access road construction - Temporary site office installation
Civil Works	- Bench earthworks - Conduit trenching - Concrete pad pours
Equipment Installation	- Land battery and inverter units - Install balance of plant equipment
Electrical Works	- Pull and terminate power/control cables - Install earthing grid - Install 33kV air-insulated switchgear
Commissioning	- Primary and secondary system testing - Energisation - AEMO commissioning - Performance testing

The Lake Bonney BESS's point of connection to the NEM is at the 33kV/132kV Mayurra substation (owned by ElectraNet) that also serves as LBWF's points of connection. An extension to the substation of an additional busbar was required to facilitate the connection of the Lake Bonney BESS. These works were carried out by CPP, on behalf of ElectraNet as the relevant Network Service Provider (**NSP**). The major works completed on behalf of ElectraNet are listed in Table 3 below.

Table 3 Scope of work under the EPC contract

Works section	List of key work items
Site Mobilisation	- Site surveying - Access road construction - Temporary site office installation
Civil Works	- Bench earthworks - Conduit trenching - Concrete pad pours
Equipment Installation	- Land battery and inverter units - Install balance of plant equipment
Electrical Works	- Pull and terminate power/control cables - Install earthing grid - Install 33kV air-insulated switchgear
Commissioning	- Primary and secondary system testing - Energisation - AEMO commissioning - Performance testing

3.3.3 Technical Overview

The key technical characteristics of the Lake Bonney BESS are outlined in Table 4 below.

Table 4 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

3.3.4 Project Timeline

The date of completion for key milestones reached throughout the Lake Bonney BESS project are given in Table 5. Detailed discussions on the timing involved in these key milestones are provided in the relevant sections below.

Table 5 Completion date for key milestones in the Lake Bonney BESS project

Key Milestone	Date Completed
Funding Opportunities Expression of Interest	Q4 CY2017
Request for Proposal Tender Process	Q1 CY2018
Preferred Supplier Selected	Feb 2018
Early Works Agreement Executed	May 2018
Funding Agreements Finalised	Jul 2018
Development Approval Granted	Aug 2018
Final Investment Decision	Aug 2018
EPC Contract Executed	Aug 2018
Site Mobilisation	Sept 2018
Civil Works Completed	Nov 2018
Battery Installation Works	Dec-18 / Apr-19
Electrical Works Completed	Mar 2019
Substation Extension Completed	Mar 2019
Generator Performance Standards Approved	Sept 2019
First Full System Strength Impact Assessment Completed	Sept 2019
Transmission Connection Agreement Executed	Oct 2019
ESCOSA Generation Licence Granted	Oct 2019
Energisation of Plant	Oct 2019
Commercial Operation Date	Nov 2019
Second Full System Strength Impact Assessment Completed	May 2020
Facility Section and Practical Completion	Dec 2019

4. Project Development

4.1 Initial Investigations into Storage Opportunities

Infigen began investigating the possibility of adding an energy storage system to its asset portfolio in 2015, and it became evident that such a project could not be developed without the assistance of grant funding. There were many factors that influenced this. The key contributors were:

- the high capital costs of an energy storage system;
- the lack of market signals/revenue opportunities; and
- the unknowns surrounding the integration and performance of an energy storage system in the NEM, particularly the FCAS markets.

Infigen continued looking to deploy utility-scale battery storage facilities to allow for an expansion of its contracted C&I customer base by providing 'firm' dispatchable capacity, limit its exposure to the spot and FCAS markets, and allow for the ability to capture revenue during sporadic price spikes.

4.2 Market Opportunity

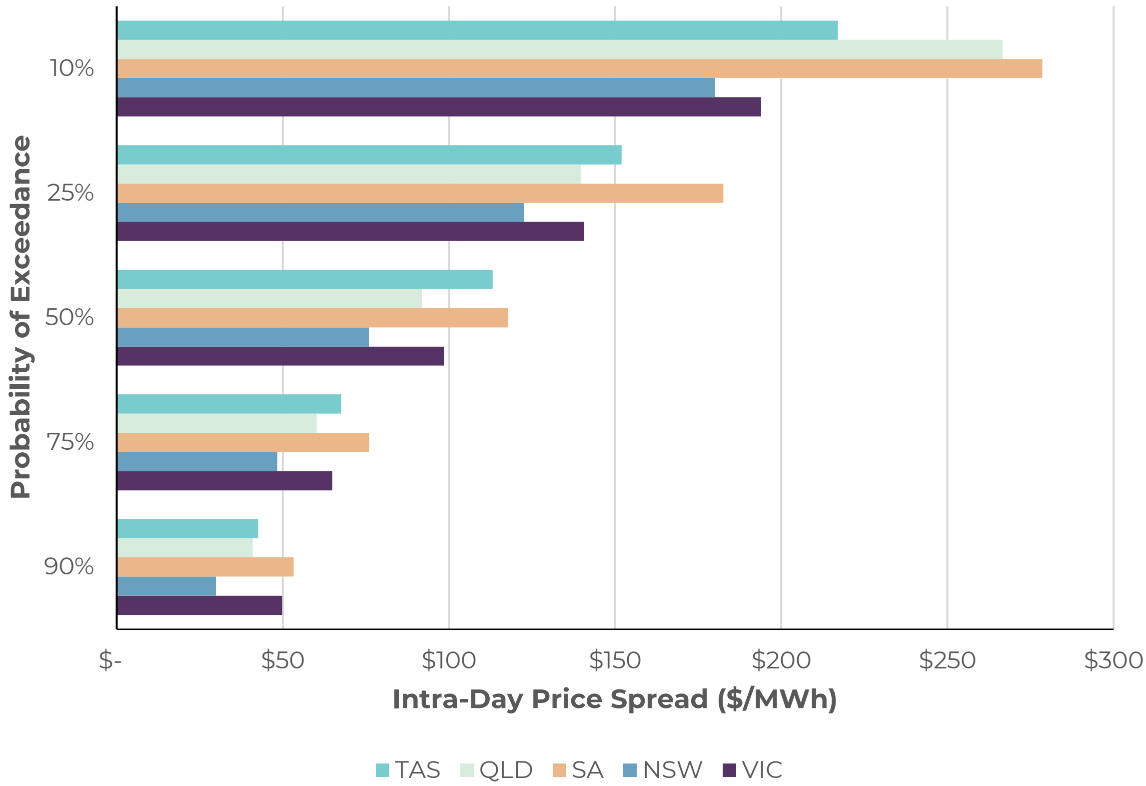
In recent years, South Australia has been the most opportune region of the NEM for a battery to operate in as the region has displayed strong revenue opportunities in both the energy and FCAS markets.

Energy market opportunity

The energy market opportunity is due to the high penetration of renewable energy and the retirement of all coal-fired generation in the SA region, both leading to greater fluctuations in spot market prices. These conditions are suitable for energy arbitrage, where the battery can charge from the grid during periods of low spot prices (typically associated with increased wind generation in SA) and discharge during periods of high spot prices (typically periods of high demand and/or reduced supply from intermittent sources).

Analysis of the intra-day price spread for the five NEM regions in 2017 shows that South Australia has the largest spread between minimum and maximum trading interval energy prices. The spreads for all five NEM regions are shown in Figure 4 below.

Figure 4 2017 Intra-day energy price spread in the NEM[1]



FCAS markets opportunity

While the FCAS markets are typically settled on a global basis (i.e. AEMO procures a certain amount of enablement in each of the 8 FCAS markets regardless of which state each provider is in), contingent risks can require AEMO to procure FCAS from specific regions. This additional enablement specific to a region is usually paid at a premium above the global settlement price of the other regions for the relevant dispatch intervals.

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[1] Probability of Exceedance (PoE) is a statistical metric that describes the probability of a particular value being exceeded.

For example, the value provided for the 75% PoE for each region will have 75% of the dataset values greater than or equal to this value, and 25% of the dataset values less than this value. Therefore, 75% of the days in 2017 in the SA region of the NEM had a difference between the maximum and minimum energy trading interval price greater than or equal to $76/MWh.

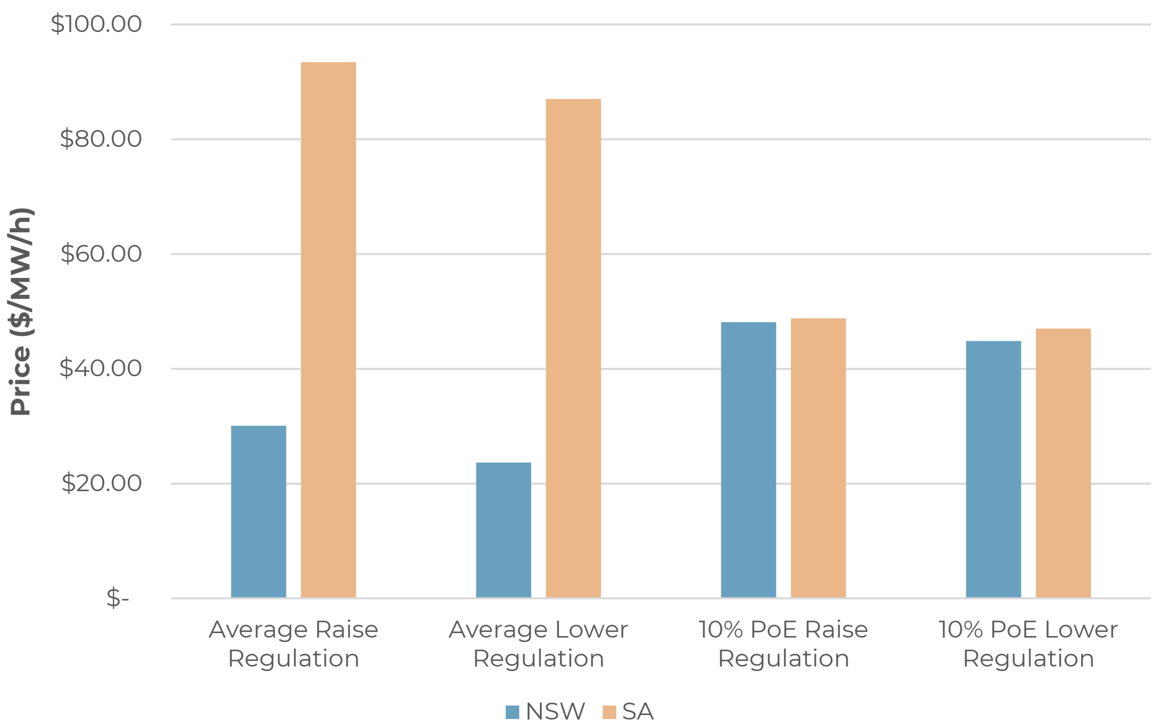
This is an important metric for energy prices as the average value can be distorted by a minimal number of extreme pricing events, so the 50% PoE is a much better indication of what normal market conditions will be than the average value.

The SA region of the NEM had historically experienced a number of intervals when local FCAS procurement was required. This typically occurred when the Heywood interconnector – the only AC link between the SA region and the rest of the NEM - is either at a credible contingent risk of being, or is, out of service.

These premium pricing events have occurred when 35MW of regulation FCAS was required to be procured locally. The impact of these pricing events on the average regulation FCAS prices for the SA region is shown in Figure 5 below for 2017, with average prices in SA more than triple that of NSW for the two regulation FCAS markets.

Also note that the 10% PoE values for the NSW and SA regions are similar, indicating that the difference in the average prices between the two regions are caused by low-frequency, high-priced events.

Figure 5 2017 regulation FCAS prices in NSW and SA



As FCAS costs are paid for by generators and/or loads, Infigen is partially liable for reimbursing the cost of FCAS, and these costs had steadily grown in the last five years. During separation events when FCAS prices are seen to have a large premium in the SA region, only SA generators and loads are responsible for reimbursement of these costs.

A BESS would be suitable for reducing the exposure to FCAS costs in two ways; by actively participating in the FCAS markets to increase the supply and reduce the cost of procuring these services (especially during constraint events) and by minimising LBWF's CPF through accruing an overly positive CPF.

Firming opportunity

The targeted growth of Infigen's C&I customer base in SA also presented an opportunity to add 'firm' dispatchable capacity to Infigen's SA generation portfolio, to reduce the risk of C&I load being greater than intermittent wind generation when the spot market prices are above the C&I contract strike price.

4.3 Funding Opportunity

Following the September 2016 black system event, the SA government established the Renewable Technology Fund (**RTF**). With the possibility of securing project funding through the RTF, a positive business case could be developed for a BESS in SA. While Infigen was unsuccessful under the initial round of grant funding (with the Hornsdale Power Reserve (**HPR**), a.k.a. the 'Tesla Big Battery', being the successful bid), it was able to enter into negotiations with both the RTF under the subsequent funding round and ARENA's Advancing Renewables Program for $5 million in grant funding, under each respective program.

With the combination of increasing market opportunities, continually falling capital costs and the grant funding available to the project, the Lake Bonney BESS was able to represent an attractive investment opportunity for Infigen.

4.4 BESS Site Location

Given the distinct market and funding opportunities, the location for the BESS was required to be in the SA region of the NEM, in which Infigen owns and operates LBWF. The wind farm was thought to be a logical site for the BESS for the following reasons:

- The existing substation located on the proposed development site would allow for a cheaper connection to the grid due to the limited augmentation works required to facilitate a grid connection and the avoided cost of a high-voltage transformer;
- Infigen is the landowner for the selected site, removing the need for landowner negotiations (and the associated time and cost), as well as yearly rental payments;
- Co-locating the Wind Farm and BESS could potentially allow for the BESS to reduce the amount of curtailed generation lost from the Wind Farm by charging from what would otherwise be lost energy; and
- The development application for a brownfield site was considered a simpler process than a greenfield site.

Box 1 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, Infigen 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.

The delays experienced due to the FSSIA are discussed further in Section 8.4.

4.5 BESS Technology Selection

Throughout 2017, Infigen was able to procure a number of offers for different energy storage system technologies and configurations. A selection of the technology options and key performance metrics are summarised below.

Lithium-ion Batteries

Lithium-ion (**Li-ion**) was the most flexible and scalable technology investigated in terms of sizing the battery system. Capacity and storage were able to be increased by adding additional containerised units – with different suppliers having different individual 'containerised' sizes. The physical space requirements of lithium-ion systems were also aligned with the project constraints.

In terms of technical performance, Li-ion has a high round-trip efficiency and a 10 to 15-year asset life. Li-ion suppliers have specific operational constraints relating to energy throughput included in their warranties and vary greatly (warranties can include daily discharge limits, annual throughput limits, etc.). These warranties guarantee the storage retention of a BESS as it degrades, typically at 2-3% each year.

Flow Batteries

In comparison, flow batteries have a lower round-trip efficiency than Li-ion technologies but are easier to scale to larger storage capacities. Flow batteries do not suffer from any degradation, so have no operational constraints or throughput limits, and can last up to 25 years.

Thermal Storage Batteries

Thermal storage batteries have an efficiency similar to flow batteries, which again is much lower than for Li-ion. If heat energy was accounted for in round-trip efficiency, this value would be much higher. Thermal storage batteries had the slowest ramping time of the compared technologies, meaning that participation in the fast FCAS markets might not be possible for some supplier solutions.

Of the storage technologies investigated, those which utilised Li-ion technology were best suited to Infigen's purposes.

Box 2 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 Infigen 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.

The major benefits of choosing a Li-ion based battery technology for the project were:

- Proven ability for achieving grid integration due to the HPR;
- Proven ability to participate in FCAS markets, de-risking key revenue streams;
- Minimal infrastructure and space requirements to construct a facility, with most solutions being containerised;
- Competitive capital cost on a MW and MWh basis;
- High round-trip efficiency;
- Extremely quick response times to internal and external control signals; and
- Scalability of system size.

The major deterrent from using Li-ion batteries in the project when compared with other options available was the energy storage degradation rate. Comparatively, flow batteries are marketed as having very little to no degradation over time, while a Li-ion battery may lose around 30% of its storage capacity over a ten-year operational life (with this figure potentially increasing due to adverse environmental conditions or an aggressive operating protocol). However, this degradation risk could be managed through a combination of an annual energy retention guarantee included in the battery warranty, and a complementary operating protocol.

Out of the Li-ion based technologies that were looked at, the preferred supplier was chosen to be Tesla. This was due to:

- Tesla's experience in connecting in the SA region of the NEM through the HPR project;
- Tesla's price offering was, at the time, cost-competitive against other Li-ion battery suppliers;
- Tesla's proprietary AutoBidder software would allow for revenue to be realised from the battery system through its autonomous bidding submissions without the need to integrate a third-party software solution to manage dispatch optimisation.

4.6 BESS Sizing Optimisation

In parallel to the selection of a BESS technology supplier, the process of determining the optimal sized BESS for the site was undertaken. This process accounted for the capital cost impacts of additional MWs of power capacity or MWhs of energy storage provided by the potential battery suppliers.

This assessment highlighted that the best option for the Lake Bonney site was a 25 MW battery with 52 MWh of storage. This result was justified by:

- Revenue modelling that showed that the BESS maximised economic value via the combination of markets, including energy arbitrage, regulation and contingency FCAS. It was the FCAS markets which accounted for the majority of value, providing around 40% to 70% of modelled revenue. These markets do not require extensive hours of storage as they are fairly reflective of a capacity market. The process of revenue modelling is discussed further in Section 6.1.

— The hours of storage available for a battery is not a flexible value, with the chemistry of the battery dictating the optimal hours of storage available. Using the battery outside of its optimal range can lead to increased degradation and loss of value of the system.
— The chosen battery size had a capital cost that matched the available equity contribution of Infigen at the time, while still having a significant portion of the capital cost covered by the grant funding available for the project to be able to achieve Infigen's investment criteria.
— The ElectraNet transformer proposed for the connection at the existing LBWF does not have any spare capacity under normal operating conditions when LWBF is operating at full output. Therefore, a BESS with a higher power rating would have its output constrained more often, which would be detrimental to project economics.

4.7 Development Application

4.7.1 Development Plan Consent

Prior to the lodging the development application, Infigen held a preliminary meeting with Wattle Range Council to discuss the application process. During this meeting, it was flagged that the responsible authority for the assessment of the development plans would be the State Commission Assessment Panel (**SCAP**).

The development plans submitted to SCAP contained the preliminary designs for the BESS, as well as discussing the potential impacts that the BESS could pose. Due to the current wind farm infrastructure on the proposed site and the minimal impact area of the BESS development, there were no major issues identified in the development application.

The development application also required the submission of a certificate from the Office of the Technical Regulator (**OTR**) that showed that the generator had an adequate inertial response to manage system strength. As the BESS is asynchronous and has no 'real' inertia, this requirement was substituted with Fast Frequency Response (**FFR**) capability. The substitution of inertia for FFR as per the OTR requirements meant that a 25MW BESS would have to provide 11.8MW within 250ms of a grid event, which the BESS is capable of providing.

Due to the existing nature of the site and Infigen's positive reputation in the area, there were no issues relating to community or council opposition during the application's public exhibition. The minimal size of the development also limited the impact on aspects such as vegetation removal and traffic management, while the suitability and context of the site made potential issues such as noise and visual amenity negligible.

Development Plan Consent was subsequently granted with 12 conditions of consent. The conditions of consent were aligned with Infigen's expectations, and all applicable conditions, particularly those concerning environmental and traffic management, were incorporated into the management plans of CPP. The Development Plan Consent was amended once through a variation due to changes in the layout dimensions that occurred due to design progression and optimisation.

Box 3 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.

4.7.2 Building Rules Consent

To receive the full Development Approval, required before works can commence on site, Infigen engaged a private consultant to receive Building Rules Consent (**BRC**).

With Infigen's previous wind farm developments, the long mobilisation time and site establishment period allows for BRC (or their equivalent in other jurisdictions) to be achieved prior to any construction that requires this consent taking place. Under the contract deliverables structure, Infigen normally does not receive the 'for construction' plans and drawings until after contract execution. However, the BESS project would require the 'for construction' drawings in advance of contract execution to receive BRC, as site works were scheduled to begin as soon as the contract was executed.

As the 'for construction' drawings of all BESS elements could not be produced before the scheduled site works start date, staged BRC and subsequent Development Approval was pursued. In this method, the documentation and drawings of the initial civil and foundation works were submitted to receive a stage 1 BRC, and a secondary consent was received for the site's control building once the final specification was agreed between Infigen and Tesla. This allowed for the initial site works to commence without delay while the design of other site elements was finalised in parallel, avoiding any delays.

5. Contracting Structure

5.1 Construction Contracts

5.1.1 Tesla's Early Works Agreement

Following preliminary discussions with a range of potential energy storage system providers, commercial contract negotiations began with Tesla in late February 2018, and an initial site visit occurred in early March 2018.

The original project timeframe was driven by the targeted Commercial Operations Date (**COD**) of 31st December 2018. In order for Infigen to maintain this timeframe, an early works agreement (**EWA**) was seen as necessary.

The need for an EWA stemmed from two main reasons:

1. To maintain the targeted COD, in absence of an executable version of a construction contract. Infigen had to continue to progress the design and allow for long lead items to be ordered. An EWA was therefore required to commercially define the scope of works to be undertaken by Tesla and to progress design to the stage where long lead items could be selected and ordered. The EWA allowed Infigen to maintain its expected COD by managing procurement of the Balance of Plant's (**BoP**) long-lead items, while also limiting Infigen's exposure to sunk procurement costs, to the bare minimum if the project was not to proceed.

2. Tesla required a commitment to allocate production slots and provide the supply dates of the Powerpack battery packs and inverters. As Infigen wanted to maintain its current project timeframes and secure the procurement timeframes, the execution of the EWA allowed for the supply dates of the Powerpack battery packs and inverters to be confirmed.

The final scope of the EWA, executed in mid-May 2018, contained the following deliverables:

- Detailed Design, including civil design up to IFC stage;
- Long lead electrical equipment;
- Specifications and schedule; and
- Grid connection application support (discussed further in Section 8.2)

While it was not apparent at the time, receiving the detailed design as part of the early works package help to prevent delays in applying for the staged BRC discussed in Section 4.7.2 above.

5.1.2 Tesla's EPC Contract

Infigen's chosen contracting structure for the construction contract with Tesla was a turnkey Engineering, Procurement and Construction (**EPC**) contract. The key benefits of choosing this contracting structure for the project were:

- Tesla as the EPC contractor would hold responsibility over all works undertaken on site, allowing for simple contracting of performance requirements, availability guarantees, time delays, etc.
    - If a different contracting structure was used (e.g. Design and Construct) where Tesla was only responsible for the battery performance and another party was responsible for the BoP installation, performance warranties and availability guarantees would have to be split across parties to create the same performance guarantees (e.g. Round-Trip Efficiency).
    - Using the EPC contracting structure simplified commercial discussions around liabilities and the performance testing protocol on site to validate the system's capabilities.
- Infigen's project management was greatly simplified as they were only dealing with one counterparty,
- Interface risks to Infigen across the site were removed, apart from ElectraNet's substation extension works.

The typical drawbacks of a turnkey EPC contract structure were also limited on this project, as:

- While EPC contracts contain a risk premium for subcontractor works, the cost of the Tesla equipment was significantly higher than the cost of the site works. Therefore, the risk premium paid for the site works was a minimal amount against the total contract value.
- Tesla nominated CPP as their subcontractor for the project, whom Infigen have worked with previously and have no reservations on.

For any potential future battery projects, Infigen may explore contracting options outside of a typical EPC structure if the capital cost of battery equipment decreases to a point where the risk premium paid for any subcontracting works become a material portion of the total capital cost. Infigen is also in a better position to evaluate and contract the interface risks of battery and BoP performance to provide an overall plant performance to the required specification from the experience gained in the Lake Bonney BESS project.

5.1.3 ElectraNet's Master Preliminary Works Agreement

Alongside the EWA for the construction of the Lake Bonney BESS, there was a similar requirement for an early works agreement for the connection works to be undertaken by ElectraNet. This was managed through a Master Preliminary Works Agreement (**MPWA**).

Again, due to the timeframes of the project, long-lead item procurement was included in one of the work orders under the MPWA once design had progressed to a stage where orders could be placed.

The MPWA also encompassed the key scope of works that would be necessary to finalise the connection option of the Lake Bonney BESS and develop the Generator Performance Standards (**GPS**) for the project. The GPS is a key document, as it is necessary to be agreed between the NSP, AEMO and Infigen, before being able to execute the Transmission Connection Agreement (**TCA**). The TCA is the key agreement between the Lake Bonney BESS and ElectraNet once executed, while the MPWA is incorporated into the TCA's works section.

Significant delays in achieving an agreed GPS (discussed in more detail in GPS Negotiations & Connection Studies Challenges) meant that the MPWA was in place for far longer than anticipated. This led to difficulties when site works envisaged under the connection schedule were due to begin, as ElectraNet did not have an appetite for undertaking site works without an executed TCA.

Infigen wished to maintain the connection works schedule (even if the GPS had not been finalised and the Lake Bonney BESS could not be energised), as this would prevent delays to the Lake Bonney BESS construction works, avoid having to re-mobilise specific equipment and staff to site at a later date and align the energisation date with the scheduled substation shutdown.

To overcome this issue, Infigen contracted directly with CPP to undertake the initial earthworks required to construct the substation extension, while continuing negotiations with ElectraNet to conduct the remainder of the site works without the TCA in place. This was possible as CPP is one of ElectraNet's authorised contractors, who can undertake works on their behalf. These negotiations were eventually successful, with ElectraNet completing the installation of the substation extension under the MPWA.

Box 4 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.

5.1.4 Procurement of Long-Lead Items

The procurement of long-lead BoP items as established under the EWA/EPC and MPWA/TCA contracts included the following items with the lead times set out in Table 6 below.

Table 6 Long-lead items under Tesla's EWA and ElectraNet's MPWA

Long-lead Item	Lead time (weeks)
Tesla's EWA	
Kiosk transformers	24
33kV disconnector air-insulated switchgear	24
Control room (including panel fit-out)	20
33kV cable sealing ends	16
Power cables	14
ElectraNet's MPWA	
Control cables	12
Relay, protection and automation equipment	12
Marshalling kiosks	12
Busbars, clamps and stringing conductors	12

The amount of exposure to Infigen to pay for the long-lead item procurement under both the EWA and MPWA increased over time because of cancellation costs. Infigen was comfortable taking the cost exposure risk of the long-lead items as:

- Initial electrical design works had demonstrated that the battery system could meet the GPS and ESCOSA requirements; and
- Continual progression of commercial negotiations firmed the view that the Lake Bonney BESS project would proceed.

Throughout the project, there were no issues or time delays associated with long-lead item procurement, and all BoP equipment was delivered to site in line with the expectation of the project schedule.

Along with the BoP procurement under the EWA, there was also an expectation that the EWA would secure the supply of the full complement of Powerpack units required to deliver the full 25MW / 52MWh battery. However, due to supply limitations from the

Gigafactory in the US, only ~200 of the 300 Powerpacks would be available to be delivered to site in at the required time for energisation before the end of 2018.

All of the inverters required would be available to the original schedule. However, the rating of the supplied inverters was limited to 650kVA as the newer 700kVA inverter model would not be available within the procurement timeframe. The impact of the lower reactive capability of the inverters is discussed further in Section 8.3.1.

To best accommodate this setback, a staged approach to deployment of the Powerpacks was proposed by Tesla. This proposal would result in an initial battery configuration of 25MW / 33MWh being installed by the end of 2018, with the remainder of Powerpacks to be delivered and installed to site in the first quarter of 2019.

While obviously not Infigen's preferred option, the staged approach was seen as acceptable for the following reasons:

- It allowed for the full 25MW power capacity to be available from energisation, with a battery's MW capacity more valuable on a one-to-one basis than a battery's MWh storage capacity;
- During installation of the additional Powerpack units on site, only the corresponding transformer block would be taken out of service (reducing available power by ~12.5% at any time during Stage 2 installation); and
- Tesla provided assurances that the second stage of Powerpack installations could be completed without risk to the installation teams or the operating plant.

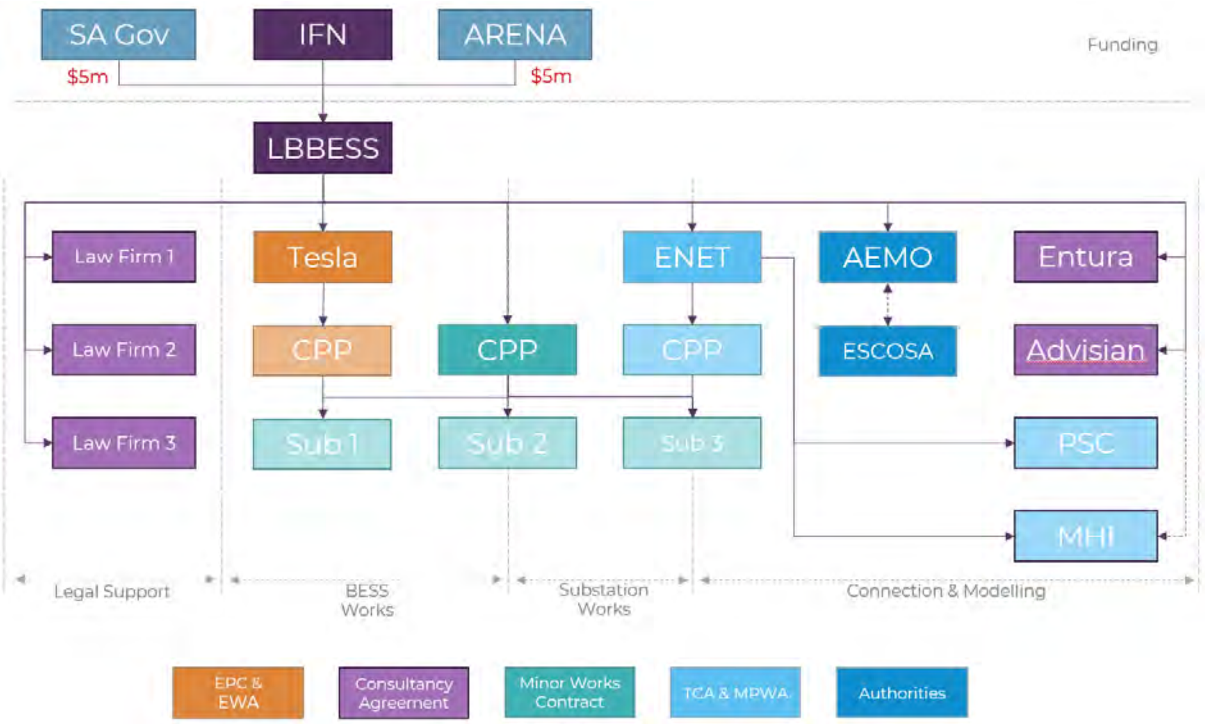
5.1.5 Grid Modelling Contract

While Infigen has the technical expertise to directly engage with AEMO and NSPs in the negotiation of an asset's GPS, it does not have the capability to develop the site-specific PSSe/PSCAD models needed for power system modelling, nor to perform the required studies using those software packages. To assist Infigen in completing the connection studies required to submit a connection application, Entura was engaged as our modelling consultant. Entura's main responsibilities on this project were to provide:

- Technical support during connection studies and associated modelling requirements;
- Conduct simulations to assess the effect of the Lake Bonney BESS on the network and the system's performance against the NER technical standards, as well as the impact of co-locating with Lake Bonney Wind Farms;
- Load flow and dynamic studies (PSSe);
- Power quality assessment; and
- Documentation management, including GPS, connection studies report, model acceptance tests, releasable user guides and model data sheets, benchmarking reports, voltage control strategy, generator's data sheets.

The full contracting structure that was implemented for the delivery of the Lake Bonney BESS is summarised in Figure 6 below.

Figure 6 Lake Bonney BESS project delivery contractual structure



5.2 Operation and Maintenance Contracts

5.2.1 OEM Services Agreement

The final operation and maintenance contracts for the Lake Bonney BESS were split, with Tesla contracted to provide maintenance services for the Tesla equipment on site (mainly the Powerpack and Inverter units). The expected maintenance works to be undertaken under this agreement are minor, with the system not incurring any wear from moving parts.

The OEM services agreement contains the contractual requirement for system availability and the mechanism for calculating availability damages, while the energy retention requirement is managed through the Tesla Warranty.

5.2.2 Tesla Warranty

With the purchase of Tesla's equipment (under the EPC contract) comes a performance warranty that basically guarantees a minimum energy retention level based on two conditions, being the aggregate number of cycles and the age of the battery. The cells chemistry essentially degrades over time and as the cells are used, usage is measured in cycles, with one cycle being the cumulative energy being discharged, in any number of sequential events, that totals the nameplate rating (i.e. 52 MWh). The warranty also comes with typical clauses around design defects and workmanship.

5.2.3 BOP Services Agreement

Servicing of the BoP for the Lake Bonney BESS was contracted to a third-party provider, with whom Infigen already had a relationship through maintenance activities at the Lake Bonney Wind Farms. Tesla's core business does not include servicing of BoP equipment, hence the choice to directly subcontract this to a third party.

5.2.4 Switching Contractor

Vestas is the long term service provider for the Lake Bonney Wind Farms through the existing service contract, and given Vestas' permanent site presence, responsibility for overall site safety management, and their existing knowledge of the site as a whole, it was a logical decision to have Vestas perform the high-voltage switching. Practically this has the impact of minimising site mobilisation times for unscheduled maintenance, the coordination activities of planned maintenance (and any scheduled outages) and reduces the interface risk from a safety perspective.

5.2.5 AutoBidder Software Services Agreement

Alongside the contracts for the physical works on site, there was also a requirement for the development and deployment of the software that would manage the bidding of the Lake Bonney BESS into the energy and FCAS markets. This software was required due to the complexity of the revenue optimisation problem across the 9 spot markets that is solved for every dispatch interval (every 5 minutes), which a human operator would not be able to achieve.

To manage the dispatch of the Lake Bonney BESS, Tesla's AutoBidder software was selected due to its market-tested performance and the ease of integration between the Tesla software and hardware interfaces. The AutoBidder agreement has standard software-as-a-service provisions for functional specifications, up-time availability, service levels and test protocols.

6. Final Investment Decision

6.1 Revenue Streams

6.1.1 Revenue Modelling

The initial financial model assembled for the Lake Bonney BESS in December 2017 had the following split between the three main forecasted project revenue streams:

Energy Arbitrage	Regulation FCAS	Contingency FCAS
60%	15%	25%

Originally, over half of the forecasted value of the battery was thought to be attributable to participating in the energy market and buying power from the spot market when prices are low and selling when high.

However, the performance of the HPR battery in the FCAS markets showed that the battery was extremely effective at earning revenue from providing these services. The battery dispatch model was altered to 'redistribute' how energy was sold to match how the HPR battery was being dispatched, with regulation FCAS services having around twice as much energy throughput as arbitrage. Because of the warranty limitations, the annual energy throughput of the battery is a key constraint to the achievable energy arbitrage revenue for a battery in a given year.

This affected the final distribution of forecasted project revenue streams as follows:

Energy Arbitrage	Regulation FCAS	Contingency FCAS
30%	50%	20%

As important as an accurate dispatch model was to calculate the revenue opportunities for the battery, the model is only as good as the pricing assumptions that are used as an input. There are a number of price curve forecasts available for the energy market and given that projects have historically been financed using these price curves, the broader market is comfortable in valuing projects on an energy-only basis.

Battery projects are unique in that they require substantial revenue streams from the FCAS markets to be commercially viable under current market conditions. Long-term price certainty over the FCAS markets is difficult to achieve, both due to the limited historical period in which these markets have had an increased value, and the lack of broader market experience in valuing assets that require the use of FCAS price curve forecasts.

Box 5 Lesson learnt: Battery revenue modelling

> Infigen 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.

As well as ensuring that the project revenues were accurately reflected in the final financial model, project expenses also had to be properly accounted for. Two unique costs for the Lake Bonney BESS that could potentially be overlooked in similar projects are:

1. BESS LGC exposure

   Due to the round-trip efficiency losses of batteries, they are net consumers of energy. This means that the Lake Bonney BESS will have to surrender LGCs to cover energy losses over the project's operational lifetime, which adds an operating expense to the project.

2. LBWF outage costs

   To accommodate for the connection of the Lake Bonney BESS at the Mayurra substation, one of the two transformers was required to be taken offline which reduced the generation capacity of LBWF by 135MW (discussed further in Section 7.2.3). The costs of having this generation unavailable for the period of energisation, as well as for any commissioning tests (discussed further in Section 7.4), should be accounted for as an expense against the project.

6.1.2 Revenue Certainty

As discussed above, the current uncertainty in future prices over the project life makes a purely merchant battery asset a high-risk investment. To increase the certainty of value of the asset to Infigen, a number of portfolio benefits were assigned to the project. These included:

1. A physical hedge against LBWF's CPF reimbursement costs

   The Lake Bonney BESS was seen as a suitable hedge against higher regulation FCAS prices that would be partially reimbursed by LBWF. This meant that across the portfolio, either the battery would experience uplift in revenue due to high regulation FCAS prices or LBWF would receive an uplift in lower than budgeted CPF costs. Without the Lake Bonney BESS as part of Infigen's generation portfolio, higher regulation FCAS prices would have a large downside impact on LBWF with no upside.

2. A physical firming asset to increase C&I contracting levels

   Given the inherent intermittency of renewable energy supply, Infigen requires firming assets to protect its contract positions with C&I customers in the scenarios where the energy market spot price is above the C&I contract strike price and Infigen renewable energy production is less than the C&I customer demand. The Lake Bonney BESS is capable of optimising its dispatch to protect the overall position of Infigen's C&I customer portfolios during these scenarios, allowing Infigen to contract a higher customer load while still being able to manage the intermittent production risk of its renewable generators.

3. Diversification of revenues

   A natural protection against the uncertainty of revenue for a battery project is that it is able to earn revenue from all 9 spot markets (energy and 8 FCAS markets). This provides some protection that if the value of one market or service was to drop (e.g. contingency FCAS services), the battery would be able to adjust its dispatch strategy to optimise its revenue by participating more in the other markets (energy and regulation FCAS). The flexibility of a battery asset also means that it is well positioned to participate in potential future markets, such as FFR.

Revenue certainty also required that the battery would be able to behave in the manner in which it was modelled. To ensure this was the case, Infigen contracted the use of Tesla's AutoBidder system to manage the dispatch optimisation process and ensure that the battery asset was utilised as economically as possible.

Box 6 Lesson learnt: Importance of considering the Lake Bonney BESS as part of Infigen'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 Infigen'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 Infigen portfolio, with either the Lake Bonney BESS earning revenues in the FCAS markets or LBWF (and/or the wider Infigen 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.

6.2 Contractual status at FID

The following key agreements, approvals and contracts listed in Table 7 were executed, or in an executable form, at the time of the final investment decision for the Lake Bonney BESS project:

Table 7 Executed documents (or in an executable form**) at final investment decision

Contract/Approval/Agreement	Counterparty
ARENA Funding Agreement	ARENA
SA Gov RTF	SA Government
Stage 1 Development Approval	Wattle Range Council
EPC Contract**	Tesla
AutoBidder Services Agreement**	Tesla
Master Preliminary Works Agreement	ElectraNet

The following key agreements, approvals and contracts listed in Table 8 were still being negotiated at the final investment decision:

Table 8 Outstanding documents at final investment decision

Contract/Approval/Agreement	Counterparty
Operating & Maintenance Contracts	Tesla / BoP O+M provider
Generator Performance Standards	AEMO / ElectraNet
Transmission Connection Agreement	ElectraNet
Generation Licence	ESCOSA / AEMO
Full System Strength Impact Assessment	AEMO / ElectraNet

6.3 Key Risks to Business Case at FID

The key risks to the business case, and their proposed mitigations, are given in Table 9.

Table 9 Key project risks and mitigation steps at final investment decision

Risk	Proposed Mitigation
Cost increases under MPWA or TCA	— Increased contingencies should additional network augmentation be required — Potential for initial capital contribution to reduce annual operating charges based on final tariff proposal
Finalisation of the GPS	— Development of draft GPS to benchmark required plant performance in EPC contract — Ongoing management of the grid modelling process — Contractual mechanism around possibility of requiring increased reactive plant capability as a result of lower MVA rating of inverters
EPC Contractor insolvency risk	— Title transfer — Key project documents placed into escrow — Subcontractor direct deed and assignment of warranties
Electricity market risk	— Diversification of revenue streams — Additional portfolio benefits from Lake Bonney BESS leveraged against market prices

6.4 Project Timeline at FID

The timeline for completion of key project milestones is given in Table 10 as they were expected at the final investment decision. Note that by this stage the targeted energisation date of December 2018 had lapsed and was now targeted for February 2019.

Table 10 Expectation for completion of key project milestones

Key Milestone	Forecasted Date
Civil Works Completed	Nov 2018
Battery Installation Works	Dec 2018 / Apr 2019
Electrical Works Completed	Jan 2019
Substation Extension Completed	Jan 2019
Agreed Generator Performance Standards	Oct 2018
Transmission Connection Agreement Executed	Oct 2018
ESCOSA Generation Licence	Dec 2018
Energisation of Plant	Feb 2019
Hold Points Released	Mar 2019
Full System Strength Impact Assessment Completed	Oct 2018
Practical Completion	May 2019

7. Construction & Commissioning

7.1 Construction Project Management

7.1.1 Strategy

Considering the contract structure of the project, the Infigen project management strategy was based on the overall management of the performance of the two major contractors on the project. This entailed the following;

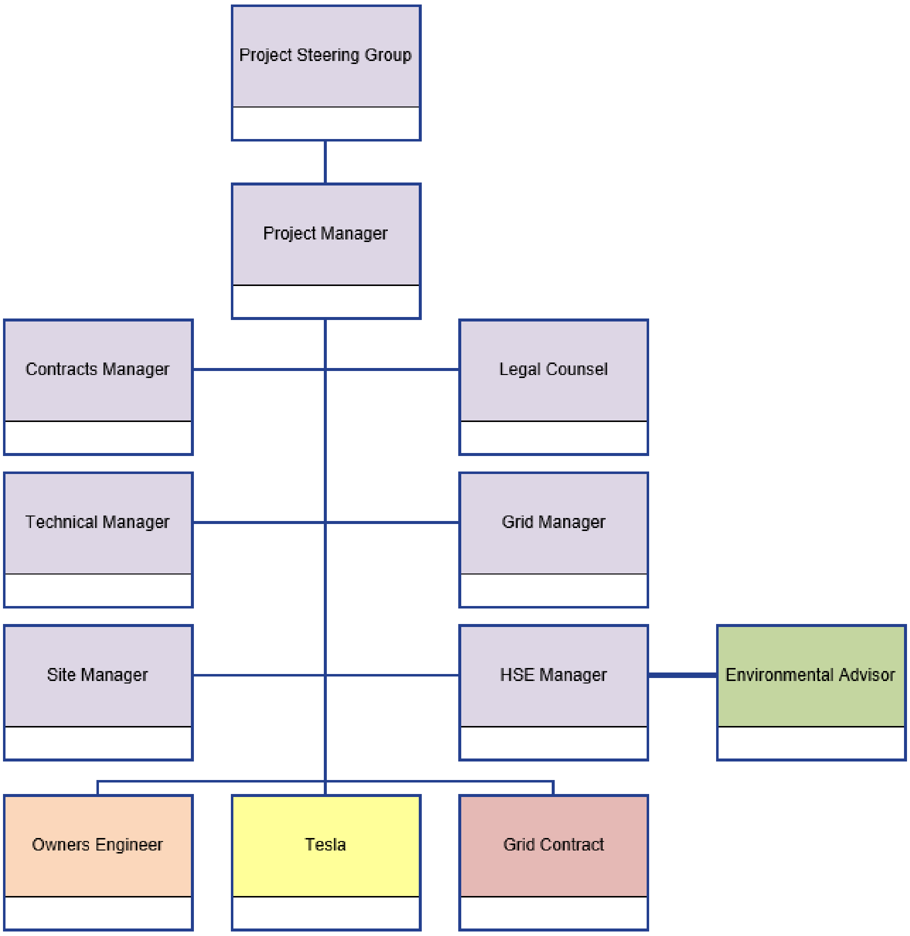
— Management of the fixed lump sum EPC contract for the delivery and installation of the Lake Bonney BESS.
— Management of the substation expansion works, being the supply of equipment, commissioning and the provision of ongoing connection services.
— Management and development of the AutoBidder baseline version.

The project team was based in Infigen's corporate office in Sydney. The project construction and commissioning phases were thought to require the dedicated resources of a construction site manager, project engineers and project controller. However, Infigen did not engage an additional resource to act as a full-time construction site manager due to comfort around CPP's personnel on site, and previous experience from working with CPP on wind farm projects.

7.1.2 Roles and Responsibilities

The key roles in the project management structure is shown in Figure 7 below.

Figure 7 Lake Bonney BESS project management structure



The responsibilities of the project team are outlined in Table 11 below.

Table 11 Lake Bonney BESS project management responsibilities

Title	Responsibility
Project Control Group	Overall corporate oversight
Project Manager	Overall project management, EPC contract management, grid interface management, third party liaison, environmental issues
Contracts Manager	Managing contracts, project administration, management of development approval processes

Technical Manager	Technical oversight civil, electrical and mechanical engineering
Site Manager	Management of Infigen's interests on site. Site interface with the EPC contractor
Grid Manager	Management of the grid connection interface
HSE Manager	HSE auditing and advice
Environmental Advisor (External resource)	General environmental advice with particular reference to flora, fauna and cultural heritage issues
Owners Engineer	Project engineering support
Tesla	BESS EPC contractor – design, supply, installation and commissioning of the project.
Grid Contract	Substation extension contract

7.2 Construction Works

7.2.1 EPC Contract Construction Works

The construction works carried out on the site under the EPC contract went largely as scheduled. Table 12 outlines the expected versus actual time taken for key construction items.

Table 12 Expected and actual time requirements for key construction work items

Work Item	**Expected Time Required (weeks)**	**Actual Time Required (weeks)**
Access road construction	3	5
Bench preparation earth works	5	6
Concrete pad pours	3	2
Landing batteries	1	1
Install MV transformers	1	1
Power / control cable terminations	3	2

As seen in the above table, the construction process faced few delays. The major point of difficulty faced in the works was the high concentration of limestone found in the battery bench area and access road, which was difficult to break apart to form a level bench, creating a time delay for the project.

No further delays were experienced through the construction works under the EPC contract until the interface works for the 33kV connection were required. This included laying the 33kV underground cable from the MV transformers to the substation busbar extension, and the installation of the 33kV switchgear at the busbar extension that was within the EPC scope of works.

Once the earthworks and civil footings were completed, the installation of the 33kV equipment was completed without incident.

7.2.2 MPWA Construction Works

As discussed in the Contracting Structure section, ElectraNet had little appetite in completing any construction works at the site without a TCA in place. However, Infigen was unable to execute this agreement due to difficulties in completing the studies necessary to agree the GPS for the Lake Bonney BESS.

The original expectation was that ElectraNet, through CPP, would undertake the civil works under the MPWA as required to prepare the substation extension busbar bench to ready the site for 33kV installation works required under both the EPC contract and the MPWA. However, these works were unexpectedly excluded by ElectraNet, and Infigen had to contract directly with CPP to undertake the initial earthwork, and subsequently the civil works, required to construct the substation extension. These works were also preceded by the requirement to relocate a Telstra service cable and wind farm communication cables that were located in the substation extension area (discussed further in the following section).

Once works were commenced, they proceeded to schedule without incident. During this time, Infigen continued negotiations with ElectraNet to allow for the completion, more specifically the commissioning portion, of the substation extension works to be completed under the MPWA. This push was partly due to a scheduled outage of Mayurra substation occurring in late March 2019 – if the planned outage was aligned with the stringing of the substation extension, then Infigen would not incur any additional costs from lost production of LBWF caused by the substation outage required during the stringing process.

Infigen were successful in the negotiations with ElectraNet to allow for the installation of the substation extension under the MPWA, which in turn allowed for the stringing of the substation extension to be undertaken during the planned outage of the Mayurra substation, with minor testing and commissioning remaining to be done upon energisation of the battery

7.2.3 Challenges of Brownfield Construction

Three key challenges due to brownfield development were identified during the construction of the Lake Bonney BESS. These were:

1. Existing underground services, both identified and unidentified

Being an operational wind farm, LBWF has a number of underground 33kV reticulation cables in the vicinity of the Mayurra substation. While the location of these cables at LBWF is well documented, they still introduced an increased risk during construction, with the battery access track route crossing one of the cables. Separate safety management procedures for works in the vicinity of the cable was required, including implementing an additional permit to work system with Vestas (who is the O&M service provider for LBWF).

Alongside the difficulties faced by known existing underground services, brownfield development and construction also face the risk of discovering unknown underground services in the vicinity of the project. This occurred during the Lake Bonney BESS project, when a Telstra cable and some wind farm fiber optic communication and protection cables were located in the substation extension area during initial geotechnical studies. These cables were later identified before being relocated prior to the earthworks for the substation extension proceeding. The contracting and undertaking of the relocation work delayed the commencement of the earthworks by around 2 weeks.

Box 7 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.

2. Selection of non-optimal location due to existing infrastructure

A clear constraint in brownfield battery construction is that the placement of the project must fit within the existing site infrastructure. At LBWF, the following site-specific constraints dictated the location of the battery bench:

— A 100m exclusion zone around all wind turbines
— The presence of underground 33kV reticulation cables for the LBWF stages

This forced the battery bench to be located on the side instead of the top of the ridge above the substation, increasing the volume of bulk earthworks required to level the battery bench. The available location also contained a high concentration of sub-surface limestone which hindered the progress of the earthworks.

3. Difficulty of aligning planned site outages for battery energisation

The connection of the substation extension busbar to the Mayurra substation required an outage that would reduce the generation capacity of LBWF by 135MW. An estimated cost to Infigen for each day's outage of 135MW is $75,000. Planned outages of Mayurra substation only occur every 3 to 6 months and are the responsibility of ElectraNet as the substation owner. Therefore, careful planning and coordination is required to ensure that the timings for the connection of the BESS and any planned outages are aligned.

This was only achievable for the Lake Bonney BESS project due to the delays in the grid connection process, allowing for the physical connection works to be completed when the next outage was scheduled, as this was not an activity on the critical path for the Lake Bonney BESS to be energised. However, despite the alignment of the physical connection works commencing at the beginning of the planned outage, the LBWF outage took longer because of the physical connection works for the BESS.

For another project that doesn't incur lengthy delays to energisation due to the grid connection process, such that the physical connection works are on the critical path, incurring the costs of an unplanned outage will likely be more economical than delaying energisation until the next planned outage. These costs should be recognised in any financial modelling, as more than likely the planned outages will not eventuate as required by the connecting asset's timeline.

7.3 Construction Progress in Pictures

Figure 8 View before Lake Bonney BESS works started

Figure 9 View after Lake Bonney BESS installation works were complete

Figure 10 Construction of the BESS pads

Figure 11 Landing of the battery packs and inverters

Figure 12 Benching works for the Mayurra Substation for the addition of the BESS 33kV exit bay

Figure 13 Installation of footings at the BESS 33kV exit bay

Figure 14 BESS 33kV exit bay and swales on the batter

Figure 15 Lake Bonney BESS – panoramic view

Figure 16 Lake Bonney BESS – birds-eye view

7.4 Commissioning Works

While some of the commissioning works could be performed before energisation, both on the Tesla and BoP equipment, a critical portion of these works hinged on energisation and connection of the facility to the NEM, which was delayed because of the connection issues and delays.

The duration of those delays was longer than anybody had anticipated, and this impacted the State of Charge (**SoC**) of the battery packs. The battery packs are shipped pre-charged at a standard level, which generally ensures that they can safely remain in storage for an extended amount of time.

However, like all batteries there are internal losses that slowly but constantly reduces the SoC. For each cell's chemistry to remain healthy and to guarantee each cell's performance, it is recommended that the battery pack SoC should not drop below a minimum level for a prolonged period of time. Due to the prolonged energisation delays, a trickle charge was supplied to the battery packs to ensure that they would remain above the minimum SoC prior to energisation to guarantee their performance once connected to the NEM.

From the date of energisation, which also required commissioning of the ElectraNet portion of works (33kV extension bay for the Lake Bonney BESS), Tesla continued their commissioning works and prepared for the two hold points tests negotiated with ElectraNet and AEMO, and subsequent performance tests required under the EPC contract.

A pre-condition to the hold point tests was the commissioning and calibration of the Automatic Generator Control (**AGC**) signal received from AEMO through ElectraNet.

7.4.1 Hold point testing

The hold point tests were agreed with AEMO and ElectraNet prior to registration and energisation. The purpose of these tests is to demonstrate compliance of the asset against the performance standards that have been agreed in the GPS.

Until the first hold point was released by AEMO and ElectraNet, Lake Bonney BESS was allowed to import or export power at up to 10MW for the distinct purpose of commissioning works (i.e. no commercial operation was allowed). The period leading up to the first hold point test allows the OEM to run some initial tests and fix any unexpected issues that may appear. Most of these issues were minor in nature and related to the final commissioning of the communication and control systems.

For Lake Bonney BESS, the second hold point test was simply a repeat of the first hold point test (i.e. the same test requirements, but at the full registered capacity of +/-25MW, instead of +/-10MW).

Each hold point test had to be coordinated with Infigen's Operation and Control Centre, and both AEMO's and ElectraNet's control rooms. The timing of these tests also carefully considered the market conditions to ensure that the Lake Bonney BESS was not exposed to extreme financial risks. Depending on a specific test's requirements, consideration of the Lake Bonney Wind Farms and the financial impact on Infigen's portfolio should they be required to be turned off or constrained was also necessary.

The hold point testing involved some of the following tests:

- Confirmation of active power dispatch control and power quality
- Demonstrating reactive power capability as per the GPS
- Demonstrating performance in voltage and power factor control modes
- Demonstrating adequate response of Lake Bonney BESS upon a voltage disturbance
- Demonstrating adequate performance against the agreed frequency droop response
- Demonstrating adequate performance upon simulation of extreme frequency excursion
- Demonstrating load rejection capability and continuous uninterrupted operation capability

All tests were successfully passed against the performance standards set out in the GPS.

7.4.2 Performance tests

Under the EPC contract, Tesla was also required to demonstrate minimum performance of the facility against a range of criteria including:

- Import and export capacities, round trip efficiency, and energy discharge capacity;
- Response time;
- SCADA data accuracy;
- Stand-by losses; and
- Reliability run over a 10-day period.

All tests were successfully passed against the criteria set out in the EPC contract.

8. Grid Connection Process

8.1 Overview of the Grid Connection Process

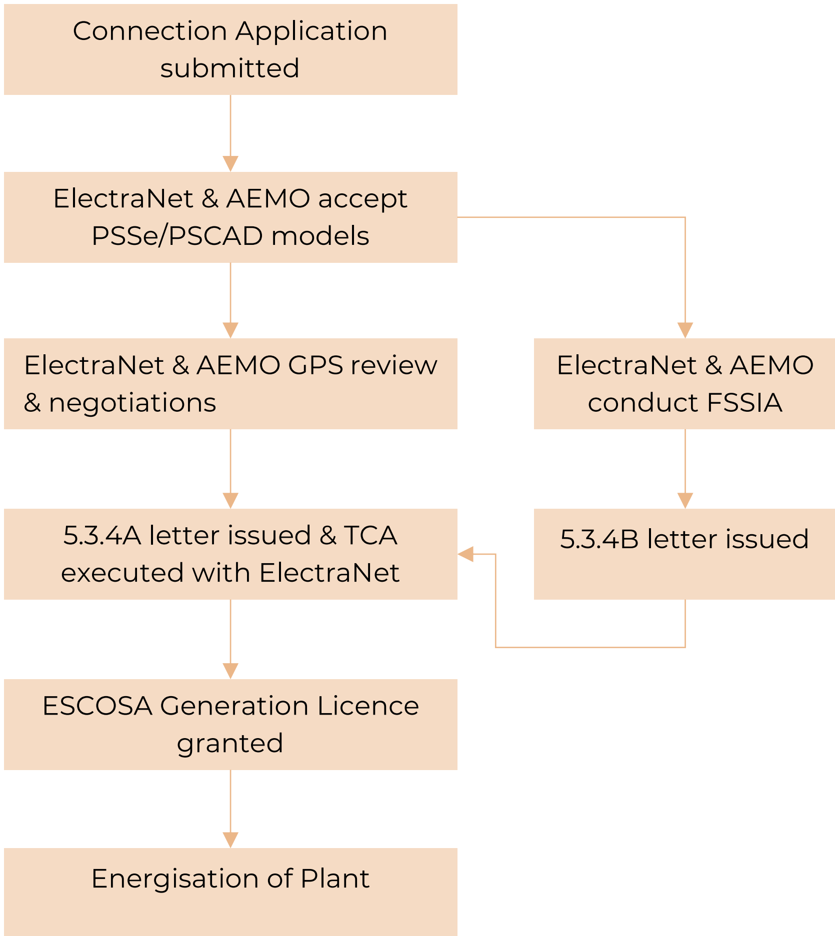
At financial close of the project, the expectations for achieving project milestones relating to the grid connection process are outlined in Table 13 below, alongside the dates that the milestones were actually achieved.

Table 13 Grid connection milestones forecast and actual achievement dates

Key Milestone	Forecasted Date	Achieved Date
Connection Application Submitted	Aug 2018	Aug 2018
Final PSSe/PSCAD Models Accepted	Sep 2018	Apr 2019
Generator Performance Standards Agreed	Oct 2018	Sept 2019
1st FSSIA Completed	Oct 2018	Sep 2019
Transmission Connection Agreement Executed	Oct 2018	Oct 2019
ESCOSA Generation Licence	Dec 2018	Oct 2019
Energisation of Plant	Feb 2019	Oct 2019
Hold Point 1 Approval	Feb 2019	Oct 2019
Hold Point 2 Approval	Mar 2019	Nov 2019
2nd FFSIA Competed	n/a	May 2020

The expected dependencies between each of these milestones are highlighted in Figure 17 below.

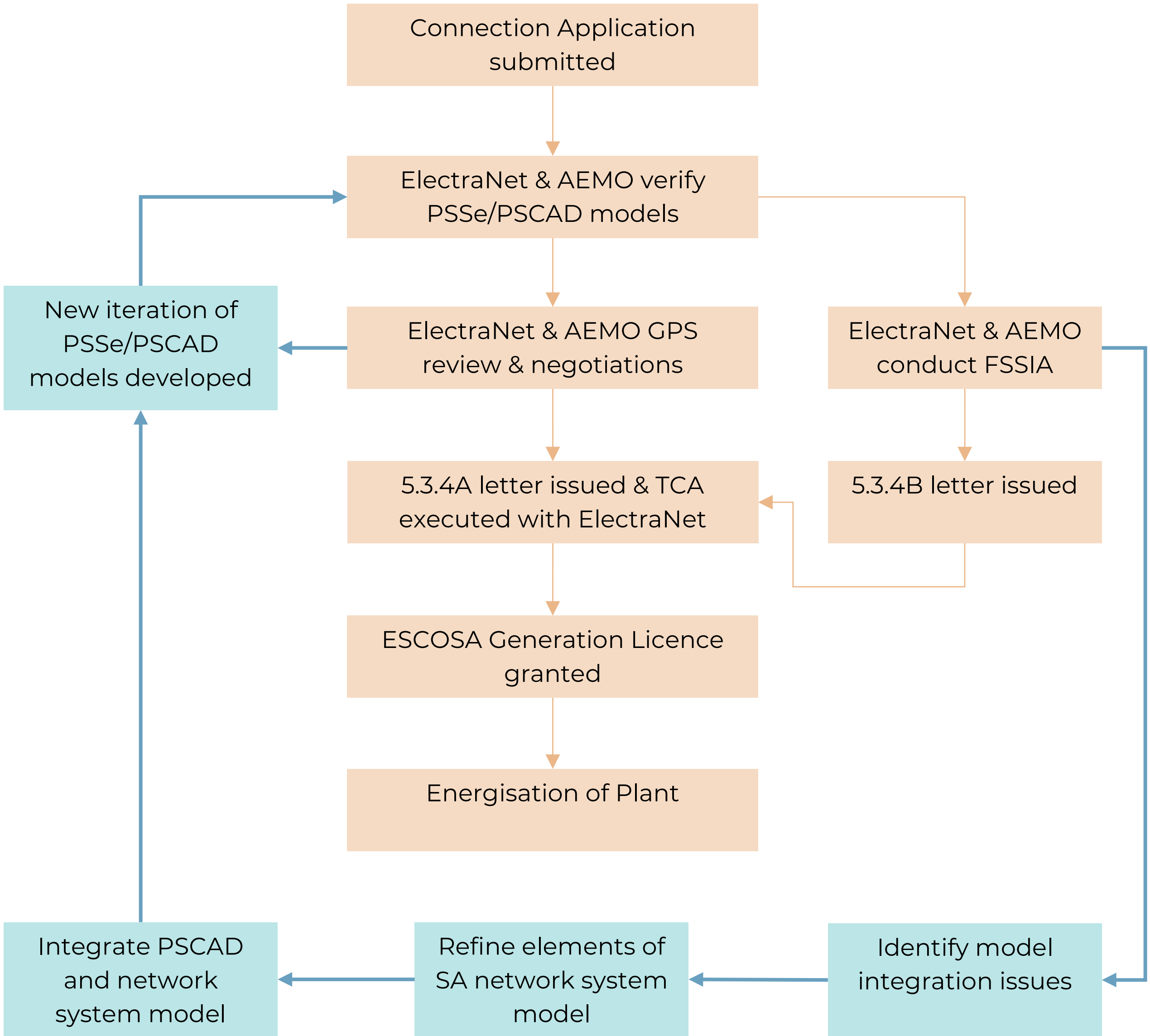
Figure 17 Expected dependencies between each grid connection milestone



The actual experiences in achieving these steps are represented in Figure 18 below. The key difference is the amount of model iterations that were required to be provided so that the GPS review and FSSIA could be undertaken.

Subsequent to this, further model iteration was required to enable the PSCAD model to integrate with the SA network model used by ElectraNet to conduct the FSSIA, with model integration issues identified after it had been verified for the purpose of undertaking the GPS review.

Figure 18 Actual experience in achieving grid connection milestones



8.2 Model Compliance

Models submitted to AEMO and NSPs are required to comply with the AEMO's Power System Modelling Guidelines. The models must be tuned such that they also comply with the agreed GPS and the ESCOSA technical requirements. During this project, many issues and non-compliances were identified which resulted in a number of resubmissions to AEMO and ElectraNet and in turn significantly delayed the project timeline.

8.3 GPS Negotiations & Connection Studies Challenges

This section provides a high-level summary of some of the topics that created issues, and/or lengthy discussions between all parties involved.

8.3.1 Reduced reactive capability of the generating system

There was a reduction in the inverter powerstage capacity (70kW to 65kW) during the project due to a limited availability of the intended inverter model. The lower rated inverter capacity led to:

- difficulty in achieving the Automatic Access Standard for reactive capability across the required voltage range (from 0.9pu to 1.1pu)
- if the Automatic Access Standard was to be enforced, this could have potentially had the effect of registering a reduced active power capacity by a few MW due to a shortfall in reactive capability at 0.9pu
- the solution was to split and define the PQ curves across three distinct voltage ranges, 0.9 to 0.93pu, 0.93 to 1.07pu, and 1.07 to 1.1pu and demonstrate that the desired reactive contribution could be provided at the extreme cases.

8.3.2 Definition of Short Circuit Ratio

Strictly using the definition of the Short Circuit Ratio (**SCR**) in the AEMO System Strength Impact Assessment Guidelines, the SCR calculated for the connection of the BESS should have been considered strong (SCR ~10). Because Lake Bonney BESS is connected to the same substation as the LBWF, this introduced some confusion as to the quanta of the generation that should be used in the SCR calculations.

- The calculation of SCR is the ratio of the calculated fault level (based on system source impedances) divided by the plant rating (both in MVA).
- SCR, rightly or wrongly, is a proxy usually used to assess system strength. A low SCR figure (<3) indicates a weak grid from a system strength point of view, a high SCR (>5) indicates a strong grid.
- Different operating conditions were assessed for connection (e.g. min and max with no credible contingency, N-1 contingency (One SE transformer out of service), and SA islanded scenario(N-2)). Those different cases create different sets of network system source impedances, which in turn change the fault level and therefore the SCR figure and X/R.
- A generator's model parameters, and site settings, will be set differently depending on the minimum SCR that it is required to operate at, in a stable and continuous manner.
- The ESCOSA requirement of being able to demonstrate capabilities at a SCR of 1.5 and X/R ratio of 2 introduced a lot of confusion during the connection studies and tuning of the Lake Bonney BESS model. The requirement is to demonstrate capability of stable operation under such network conditions. This would however

require the re-tuning of the plant's parameters, which would otherwise not be suitable for the existing network conditions.

- Lake Bonney BESS was tuned for an agreed SCR of 9.8 and X/R ratio of 10, which is vastly different from the ESCOSA capability requirements. Lake Bonney BESS is capable of operating at the ESCOSA requirements, but with adjustment to site specific parameters, which may result in different model performance and produce a different outcome on the GPS.
- To add further confusion, some of the tests required as part of the Model Acceptance Test must be performed with a SCR of 3.
- The lack of clarity and the resulting confusions impacted the tuning of the Lake Bonney BESS, especially in relation to the high and low voltage ride through parameters, and other GPS and ESCOSA requirements.

8.3.3 New GPS Requirements

Delay in the connection studies meant that Lake Bonney BESS had to, as per the rule change, comply with the new GPS requirements.

- The AEMC made rule change (Rule 2018 – no 10), which introduced significant changes to technical performance standards for generators seeking to connect to the national electricity grid, and the process for negotiating those standards.
- This rule change came on 19 September 2017 and became effective on 5 October 2018, with a transitional period extending to 1 February 2019 for proponents who already submitted their connection application or had agreed a full set of access standard before the end of the transitional period.
- However, in South Australia, most of those additional requirements were already legislated under the SA Electricity Act and formed part of the ESCOSA technical requirements, which were evaluated from a technical point of view by AEMO. So, while there would have been some benefits from a GPS negotiations point of view with AEMO and ElectraNet, AEMO would probably have had to go through the same level of technical due diligence.
- The Lake Bonny BESS application was submitted before 5 October 2018 but did not have the GPS agreed or a Connection Agreement executed, hence it fell into the transitional arrangements. Due to issues with models, it was not possible to agree a GPS by 1 Feb 2019 and hence Lake Bonney BESS was required to modify its GPS to the new Rules. This change did not have a meaningful effect to the actual standards that were required to be met due to the pre-existing standards of the ESCOSA Guidelines.

8.3.4 Theoretical Modelling Issues

There was significant discussion around interpreting modelling artefacts and the National Electricity Rules:

- No model is perfect, and every model has limitations. Because PSSe and PSCAD are used for different purposes, the results of those two models sometime differed because of the inherent limitations of each software. It was proven, on multiple occasions, that it was difficult to convince the relevant authorities who rightly always err on the side of caution, that the results of those models were directly attributable to those software/model limitations and not to the actual performance of the plant.

- During the evaluation of Continuous Uninterrupted Operation under NER S.5.2.5.4, there was quite a bit of discussion on what was considered 'substantial' in the following limb of the definition:

  > *(c) after clearance of any electrical fault that caused the disturbance, only substantially varying its active power and reactive power as required or permitted by its performance standards established under clauses S5.2.5.5, S5.2.5.11, S5.2.5.13 and S5.2.5.14; and*

- From a modelling perspective, any variation was considered as being unacceptable. A lot of discussion was required to explain that real world controls do not respond perfectly, hence leaving small, immaterial, discrepancies from modelled performance.

8.4 FSSIA Challenges

Once ElectraNet and AEMO had completed their due diligence checks on the PSCAD model supplied by Tesla to undertake the GPS assessment, the FSSIA was supposedly ready to be undertaken, from late April 2019 and was supposed to take approximately 4 weeks to complete. It took 5 months.

8.4.1 Scope of Work

Prior to starting the FSSIA, the NSP needs to agree with AEMO the exact scope of works and the scenarios that are going to be investigated as part of this impact assessment. One of the difficulties Infigen had as an applicant, was to have any visibility on what this scope was and what was the status of the negotiations/discussions/agreement between AEMO and ElectraNet. Ultimately this has the potential to further delay the project but also creates a scenario where the applicant has no control whatsoever on the scope and therefore the cost of that study.

8.4.2 Integration Issues and IP Limitations

The FSSIA also requires the integration of the site-specific PSCAD model for the Lake Bonney BESS within ElectraNet's system model. The system model chosen for that assessment was limited to the South-East of the SA region of the NEM. This system model includes other dynamic models such as the LBWF Vestas' turbine models and the AMSC's DVAR reactive plant models. It also includes nearby customer loads and market generators, involving other OEMs and market participants.

The ElectraNet modelling team experienced issues when trying to initialise their model with the site-specific PSCAD model of the Lake Bonney BESS. If the model was initialised with either the existing LBWF and reactive plant models, or with only the BESS model behind Lake Bonney's connection point, their system model would load successfully. However, if both the wind farm models and the Lake Bonney BESS model were loaded in a single case, the overall system model would fail to load.

Unlike modelling issues that were encountered during the GPS assessment, where consultants and/or the OEM could replicate the conditions that lead to particular errors or issues, the state-wide PSCAD model is not accessible to Infigen, and contains black boxed models that are also not accessible to NSPs due to Intellectual Property limitations. As such, there was no way to replicate the behavior that was observed by ElectraNet and made it impossible for us to understand or resolve the issues observed. Infigen's first step to resolve the issue was to engage with the developer of the state-wide model, Manitoba Hydro, so that they could investigate the model issue directly and advise which change were required to be made. This however required their engagement under a strict confidentiality agreement, but also necessitated most OEMs involved to enter into mutual confidentiality agreements that Infigen had to organise but had no commercial leverage to practically ask anyone to do anything.

Manitoba Hydro was subsequently engaged by ElectraNet, because issues were being picked up which were possibly related to other market participants, or the system model itself and for which Infigen could not be informed of, under the confidentiality requirements of the NER.

In retrospect, it is not surprising that models of plants connected under much older versions of the NER which at the time did not mandate the provision of such elaborated PSCAD models prove to have shortcomings when used in the assessment of other plants, whose performance and expectations is dictated by the latest rules and requirements. This is an even bigger problem for an applicant such as Infigen to manage, when there is no access to those models and no insights to what the problem could actually be.

To some extent, Infigen was lucky to also be the owner of the Lake Bonney Wind Farms and could assist in this process, but should another market participant have created an issue, this would have been considerably harder to resolve.

Box 8 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 Infigen 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.

8.4.3 Results of the First FSSIA

As a result of the LBWF's model shortcomings, ElectraNet and AEMO imposed various constraints on Lake Bonney BESS:

- a combined constraint on LBWF's + Lake Bonney BESS' output of 268MW
- the inclusion of Lake Bonney BESS in the regional non-synchronous generation system constraint for SA
- A constraint that binds on Lake Bonney BESS when all D-VARs of the LBWF are out of service capping its output to 22MW.

ElectraNet and AEMO also requested Infigen's assistance to update and refine the LBWF's models such that a second FSSIA could be undertaken. Practically speaking the first FSSIA was started in May 2019 and concluded at the end of September 2019, taking 4 to 5 months.

8.4.4 Second FSSIA

The second FSSIA presumably started in around December 2019 and was concluded at the beginning of May 2020, taking another 4 to 5 months.

The outcome of this second assessment was that the connection of the Lake Bonney BESS does not cause an adverse system strength impact on other existing and committed generating systems and that, on this basis, a System Strength Mitigation Scheme is not required.

The combined LBWF and Lake Bonney BESS constraint has been removed and the two other constraints will be reconsidered at the completion of the R2 process.

Importantly, while ElectraNet and AEMO were undertaking this second FSSIA, this did not prevent Lake Bonney BESS to operate commercially, at full capacity.

Box 9 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.

8.5 Other Connection Challenges

8.5.1 Coordination Deed

All three Lake Bonney Wind Farms already had their respective Transmission Connection Agreements and Generator Performance Standards. During the negotiations of the Transmission Connection Agreement (**TCA**) for Lake Bonney BESS with ElectraNet, ElectraNet introduced a document called Coordination Deed but for which they were not ready to provide any details until very late in the negotiation and connection process. That document was to become a necessary condition precedent to the execution of the TCA.

In practical terms, this Coordination Deed seeks to aggregate the responsibilities of the 4 generating assets that connect to the ElectraNet owned Mayurra substation, in order to guarantee to ElectraNet aggregated limits for harmonic voltage distortion, voltage unbalance and voltage fluctuation levels. This obviously makes it much easier for the NSP to manage their own emission levels, but practically this links different generating assets and imposes obligations above and beyond what is otherwise contemplated under the NER.

One of the main challenges for Infigen was to ensure that the aggregate limits that were to be imposed were realistic and not more stringent than the sum of the individual limits under each GPS.

Another challenge was to accept that different assets would be forever linked under a coordination deed, which would make it more complex to sell that asset that would come attached with obligation to coordinate with third parties. Again, similar to the issues encountered during the FSSIA, Infigen was somehow lucky to also be the owner and operator of the Lake Bonney Wind Farms, but this would have been a much more complicated process should those wind farms be owned and/or operated by third parties.

8.5.2 ESCOSA License Timing

The ESCOSA generation license is a requirement for SA generators with a rated nameplate output of more than 100 kVA, who supply electricity for reward by means of a transmission or distribution network.

At FID, ESCOSA advised that a 12-week timeframe was necessary from application to granting of the licence, including a mandated 4-week public exhibition of the licence application. However, this timeframe quickly increased to 16-20 weeks given the large number of submissions received by ESCOSA in late 2018, mainly attributed to a large number of small (<5MW) solar farms applying for generator licences. These applications are all considered in the same manner as large-scale projects.

The ESCOSA commission also only meets once a month to give the final approval to applications. These applications undergo an executive review before being presented to the commission, so submission of the completed licence application is needed weeks prior to these monthly meetings. There is a risk that if there are a number of applications to consider in a given month, or the application is not quite ready for final approval, that the licence approval will be delayed by four weeks.

Box 10 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.

8.5.3 AEMO Registration

As discussed above, due to the delays associated with the GPS and FSSIA, the registration process for the Lake Bonney BESS as a generator, and as a load, was not on the critical path for energisation.

Registration is a key process that links multiple departments within AEMO to collect the necessary information and ensure that everything is in place for the generator, and/or load to be connected. Every project should allow sufficient time for that process to take place, and here we note some areas which proved more difficult than others for the project:

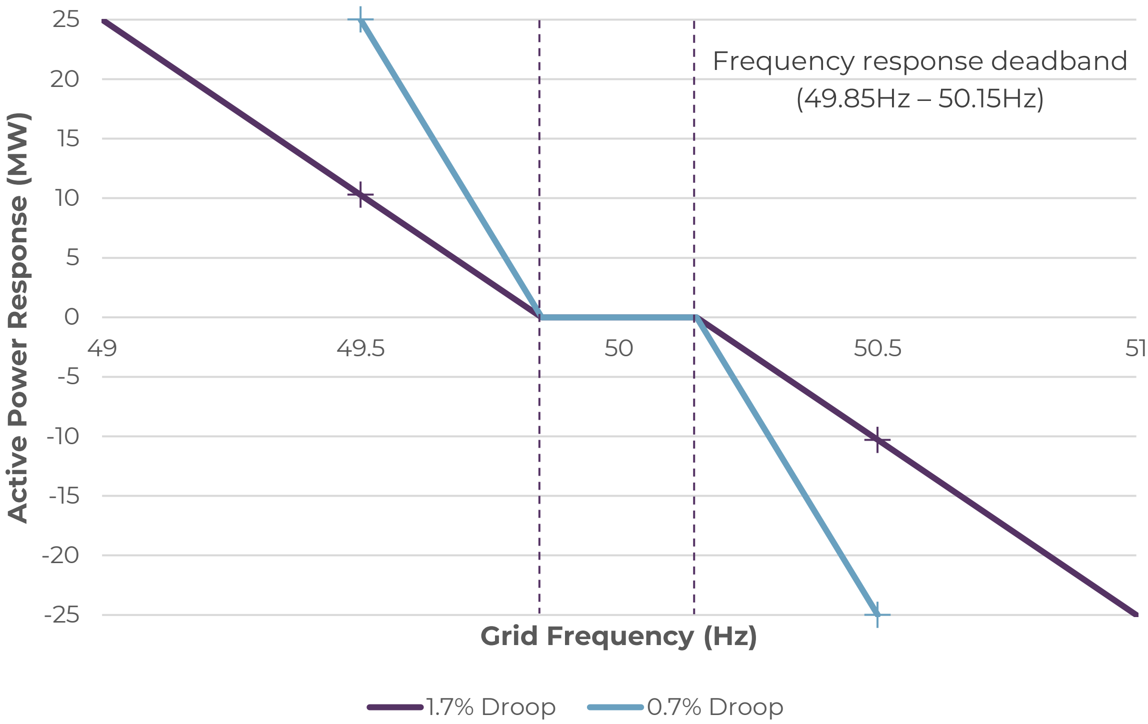
- A considerable amount of time was required to finalise the SCADA points list with AEMO and ElectraNet. The SCADA end-to-end point testing requires the asset to be built and partially commissioned;
- the draft commissioning plan is required to be developed at least three months prior to expected energisation;
- deployment into the AEMO pre-production environment and setup of the data sharing agreement between all the Infigen's owned assets proved difficult and time consuming
- As batteries were a somewhat new category, there were some uncertainties as to how batteries should be registered, mostly in relation to the aggregation of individual units and allowable ramp rates.

8.5.4 Contingency FCAS Registration

Prior to January 2019, AEMO had not provided clear guidance on what droop settings could be registered for the Lake Bonney BESS. The droop setting, which dictates the active power response of the BESS based on the frequency of the grid, is the key parameter that dictates the amount of contingency FCAS services that can be registered for a BESS.

For a 25MW BESS similar to the Lake Bonney BESS, a droop setting of 1.7% (as recommended by AEMO for a BESS) results in an active power response of ~10MW of discharge power at 49.5Hz and an identical magnitude charge response at 50.5Hz. However, a droop setting of 0.7% would result in the full 25MW power response of the BESS being provided as either a discharge or charge response at 49.5Hz and 50.5Hz respectively, as seen in Figure 19 below.

Figure 19 Active power responses for a 25MW BESS with a 0.7% and 1.7% droop setting



These responses at 49.5Hz and 50.5Hz respectively dictate the average capacity that can be registered across the three contingency markets for either a raise or lower response.

In the NEM currently, there is a discrepancy around the average registered contingency FCAS capacity for BESS participants as a portion of its nameplate power capacity, as shown in Table 14 below.

Table 14 Average registered contingency FCAS capacity as a percentage of nameplate capacity

BESS Participant	**Average Registered Contingency FCAS Capacity (% of Nameplate Capacity)**
Hornsdale Power Reserve (100MW with its contingency FCAS capabilities)	~40%
Dalrymple BESS	100%
Ballarat BESS	100%
Gannawarra BESS	0%
Lake Bonney BESS	~40%

Given the large portion of revenue that can be attributed to providing contingency FCAS, the lack of transparency around what registration is possible for different installations makes building a complete business case difficult (as a developer will be forced to assume only being able to register ~40% of the nameplate capacity in the contingency FCAS markets).

It also makes it difficult for the market to calculate the growth of market providers, and whether the announcement of 100MW of batteries in the NEM will provide an extra 40MW or 100MW of capacity into the contingency FCAS markets. Given the relatively small size of these markets, and the high participation rates of batteries in these services, this also has a material impact on planning for future revenues.

Box 11 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.

8.5.5 Transformer Capacity Management Strategy

The Lake Bonney BESS is connected to one of two 33/132kV transformers at Mayurra substation, which has a rated capacity of 145MVA. Given that this transformer is utilised by 135MW of capacity from LBWF stages 2B and 3, there is no spare capacity for the battery to discharge when the LBWF stages are operating at full capacity.

While this constraint was well understood throughout the project, there was an opportunity for Infigen to implement a control scheme that would allow for the Lake Bonney BESS to

[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

provide contingency FCAS even if LBWF was operating at full capacity. This was because contingency responses are always enabled but rarely required, so there is a low probability of the transformer capacity being overloaded by a contingency FCAS response, and if this was the case, it could be allowed for a short period of time, which would be valuable for the power system.

After consultation with ElectraNet, the rating of the transformer was increased to allow for a 10-minute overload to a rating of 156.1MVA only when the grid frequency falls below 49.85Hz. This ensures that the Lake Bonney BESS can provide its contingency response of 10MW to comply with its maximum possible enablement but would have to stop providing contingency raise FCAS after the 10-minute overload period. The overload capacity being conditional on the grid frequency being below 49.85Hz prevents Infigen from overloading the transformer under normal grid conditions.

8.5.6 "Behind the Meter" Charging

An additional benefit of co-locating the Lake Bonney BESS at the LBWF was the potential for the BESS to utilise 'behind the meter' charging. This was envisioned to occur in periods where the output of LBWF was constrained due to thermal or stability limits. Instead of the additional generation being lost due to the constraint, the BESS would be able to be charged so that the net output of the LBWF was still not in breach of the export constraint.

However, this option was deemed to be too high risk to pursue, as the implementation of behind-the-meter charging would have required the registered GPS of the LBWF to be re-opened. Indeed, the Lake Bonney wind farm (stage 2 or 3) would have had to include the Lake Bonney BESS behind its point of connection creating a hybrid generating system, which would have necessitated a modification to the existing GPS and registration.

Infigen are still looking to capture possible opportunities where thermal constraints limit the combined output of all four generators at the Mayurra substation (not at the individual connection points). It is viewed that in these circumstances new opportunities could arise to increase production (and LGC creation) from LBWF whilst charging the battery - notionally creating a 'behind the meter' outcome.

While these constraints are historically common there hasn't been many opportunities since the Lake Bonney BESS was commissioned to test out the nuances of achieving this optimisation. This will continue to be pursued when opportunities present themselves.