October 2021

KNOWLEDGE SHARING REPORT

Ballarat Battery Energy Storage System

FINAL KNOWLEDGE SHARING REPORT
OPERATIONAL YEARS 1 & 2

The Consortium

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Disclaimer

The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

PART I
Project Overview

1.1 Introduction

The Consortium is pleased to provide this knowledge sharing report that outlines the performance of the Ballarat Battery Energy Storage System (Ballarat System) over the first 24 months of operation.

The purpose of this report is to share the key learnings over the 24 months of operation of the Ballarat System as part of the Consortium's obligations with ARENA and DELWP under the Knowledge Sharing Agreement. This document is intended to be released to the public and covers the following key areas:

- Operational Performance;
- Market Services;
- Network Revenue Opportunities; and
- Technical Challenges

The Ballarat System is a consortium project undertaken by the Spotless / Downer Group, Fluence, AusNet Services, and Energy Australia. The project was selected during the Victorian Government Energy Storage Initiative tender process and is one of two projects under that program to be constructed and now in operations. The Victorian Government and the Australian Renewable Energy Agency (ARENA) through the Advancing Renewables Program contributed $25 million in grant funding for this project.

The project is the first of its kind in Australia -- a standalone battery-based energy storage system being installed in front of the meter and directly connected to the transmission network -- and the first grid-scale battery-based storage system commissioned in the state of Victoria.

The Ballarat System is a 30MW / 30MWh system utilising Lithium-ion battery technology and Fluence's proprietary hardware and software controls. The system is installed at Ballarat Terminal Station (BATS) and is connected to the transmission network via the BATS No.1 transformer tertiary winding (rated at 22kV 40MVA). The Ballarat System is registered to operate as a 30MW generator, a 30MW load, and to provide regulation Frequency Control Ancillary Services (FCAS) raise and lower as well as all six contingency FCAS markets. The Ballarat Terminal Station is the central hub for the electricity transmission network in western Victoria and the location was chosen to add new capabilities at AusNet Services' existing facility to support further renewable electricity generation, in addition to over 620MW of existing local renewable energy generation.

The project was constructed in nine months during 2018 and was completed and capable of dispatching services for all eight FCAS markets and energy to the NEM on 22 December 2018. Providing capacity comparable to 6,000 residential battery storage systems at a single location, the project was designed to provide the following outcomes:

1. To enhance network stability and reduce congestion on Victoria's transmission grid through direct grid connection and participation in both Australia's National Electricity Market's (NEM) contingency and regulation Frequency Control Ancillary Services (FCAS) markets; and
2. To add a peak power resource to help manage price volatility and reliability risks during high demand periods, by providing a reliable energy source to the Australian Energy Market Operator (AEMO)

1.2 Project Overview

The Ballarat System commenced commercial operations on 22 December 2018 and is owned and operated under the following structure:

- EnergyAustralia as the Market Intermediary, operating and trading the system in the National Energy Market (NEM) in accordance with the Operating Parameters;
- AusNet Services/Mondo as the asset owner, with a service agreement with EnergyAustralia for use of the Ballarat System in the NEM in accordance according to the Operating Parameters;
- AusNet Services/Mondo contracts Fluence under a 15-year services agreement ("Term") to ensure the battery system is available for use according to the Operating Parameters; and
- AusNet Services maintains the Balance of Plant to ensure the system is available for use according to the Operating Parameters.

Operations and maintenance (O&M) responsibilities are summarised in Figure 1.

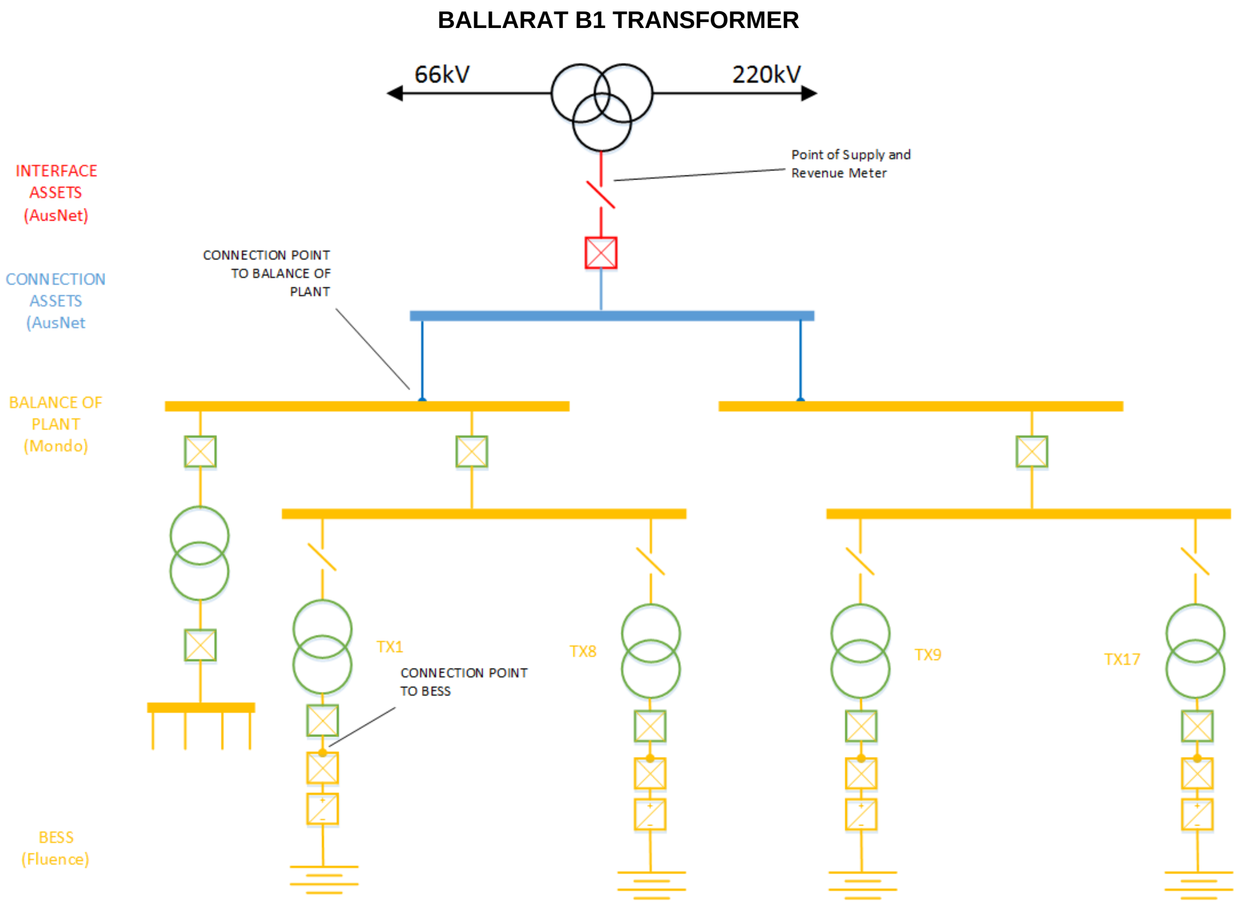

Figure 1 – O&M Responsibilities

1.3 Project Stakeholders

The Ballarat System is a project undertaken by the Consortium comprising of Spotless / Downer Group, Fluence, AusNet Services and Energy Australia. With Spotless taking the lead in forming the Consortium, Fluence supplying and maintaining the Battery Energy Storage System, AusNet funding and owning the asset, and Energy Australia acting as the market intermediary.

As a project identified under the Victorian Government Energy Storage Initiative program and additionally eligible for ARENA's Advanced Renewables Program, Ballarat System received funding from both the Victorian Government and ARENA, making the Victorian Government and ARENA funding partners and key stakeholders in this project.

Other stakeholders included AEMO, who assisted in the network studies, the City of Ballarat and the broader Ballarat community whose support was imperative to the successful integration of the project.

1.4 Project Timelines MONDO

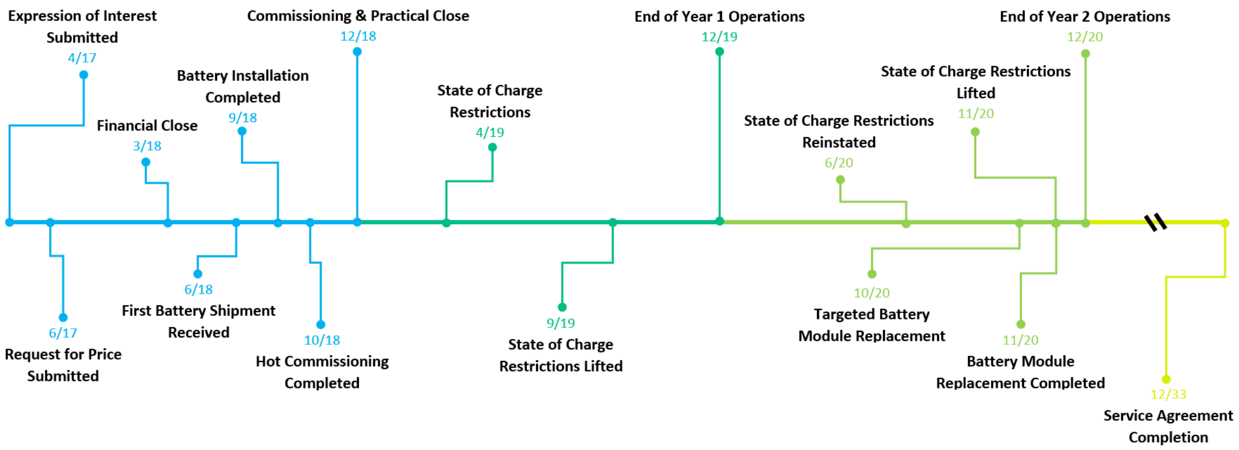

Figure 2 - Key Event Timeline

1.5 Project Risks & Mitigations

The Consortium faced several safety, procurement, construction, operational and financial risks throughout the project development stage and in the first 24 months of operations. The associated project risks varied for each Consortium member, who all had different mitigation strategies for their respective risks.

AusNet Services/Mondo had never undertaken a battery project prior to the Ballarat System and thus this project was an opportunity for the organisation to explore the rewards and challenges of owning and operating a battery asset. This organisation had a considerable risk appetite for this project as the leanings would shape future battery projects. By engaging in the Consortium, many of the risks associated with a new technology could be mitigated.

The procurement, construction, operations and maintenance were contracted to Downer and Fluence, whose team have deployed the first grid-scale lithium-ion battery system in the world and brought to the project extensive experience in deploying and operating energy storage products globally. However, the Ballarat System was Fluence's first deployment of a grid-scale battery-based energy storage system in Australia and therefore Fluence was exposed to the inherent risk attributed to breaking into an emerging market. In particular, the process of finalising commissioning and securing interconnection in the NEM was more complex than in many other markets around the world. Since batteries are a relatively new technology being deployed in the National Electricity Market, Fluence was exposed to deployment risks associated with commissioning a system in a market where standards for how a bidirectional asset (serving as both generator and load) could be connected and operate had not yet been created. To manage this, Fluence and AEMO worked together to jointly develop a R2 testing regime for commissioning a battery system (i.e., bi-directional asset that could serve as generator and load). In addition, some early technical issues needed to be managed between the deployment team and support personnel in the United States, which was later mitigated by establishing a local servicing team in Australia.

Furthermore, the role of market intermediary and trading was contracted to EnergyAustralia who is an experienced generator in National Electricity Market. However, as the long term off-taker and market intermediary for the project, EnergyAustralia takes long term price risk of the project. This means EnergyAustralia is exposed to changes in market prices over the life of its tolling contract which are inherently uncertain. This risk is managed through EnergyAustralia trading capability within an integrated generation and retail portfolio. EnergyAustralia is also exposed to asset performance risk, where for example, when the battery does not perform as planned EnergyAustralia can experience a reduction in market revenues. This is managed in the Consortium through performance regimes built into contractual arrangements between the asset owner (AusNet) and the battery supplier (Fluence), however these regimes can be complex and difficult to manage.

PART II
Operations Report

2.1 Safety & Environmental Performance

Safety performance for Contract Year 1 and 2of the Ballarat System was measured by safety events occurring that resulted in a Lost Time Injury (“LTI”) on the project site. Fluence and AusNet Services worked closely to ensure that site works and ongoing operations and maintenance of the Ballarat System were performed to the highest safety standards, resulting in an exemplary safety record with zero LTIs taking place during the first two years of operation.

From an environmental perspective, the Ballarat System, similar to other battery assets, has no direct emissions, fuel consumption or wastewater impacts and emits minimal noise beyond the acoustic barrier at the Ballarat Terminal Station.

2.2 Technical Performance

Operating parameters for Contract Year 1 and 2 of the Ballarat System are presented in Table 1. The Operational parameters for subsequent years are reduced in accordance with the nominated degradation curve.

Table 1 – Operating Parameter Summary

Parameter	Requirement – Contract Year 1	Requirement – Contract Year 2
Availability	$Availability\ (\%) = \frac{Capacity}{Rated\ Power}\quad (averaged\ over\ all\ periods)$ Where, for each Period: Capacity is the lesser of: (i) Actual Available Capacity; and (ii) $\frac{Actual\ Available\ Energy}{Usable\ Energy} \times Rated\ Power$	
Rated Power	30.38 MW	**30.38 MW**
Usable Energy	30.38 MWh	**29.07 MWh**
Round Trip Efficiency	87.17%	**86.80%**

The performance of the Ballarat System for Contract Years 1 and 2 are summarised in Table 2.

Table 2 – Key performance summary

	Actual
Availability for Contract Year 1	86.36% (Availability for Contract Year 1 excluding SoC restriction – 95.65%)
Availability for Contract Year 2	91.05% (Availability for Contract Year 2 excluding SoC restriction – 98.92%)
Availability for Contract Years 1 & 2	89.89% (Availability for Contract Years 1 & 2 excl. SoC restriction – 97.92%)

Other key performance parameters from the Ballarat System for Contract Years 1 and 2 and are provided in Table 3.

Table 3 – Key performance parameters

Parameter	Actual (Contract Year 1)	Actual (Contract Year 2)
Cumulative energy discharge (i.e., FCAS provisioned/energy sales for arbitrage)	7312.0 MWh	5639.1 MWh*
Deep Discharge	1 event maximum per 24 hours 45 events	2 events maximum per 24 hours 43 events
State of Charge	34.1% average SoC 14 times at >50% SoC for 14 to 20 hours	35.4% average SoC 10 times at >50% SoC for 14 to 20 hours

**Note – Energy contributed to the NEM was 5,611 MWh*

A deep discharge event is defined as the SoC of the system during a discharge event going from greater than 80% to under 20% during the event.

For the Ballarat System there is a limit in the average SoC allowable over the course of the year due to the hardware and software installed. These limitations are identified above regarding the SoC.

2.2.1. Availability

The SoC restrictions placed on the battery in Contract Years 1 and 2 (detail provided in section 2.5.2) impacted the availability of the Ballarat System similarly. Despite this, the availability of the Ballarat System in year 2 of operations exceeded the availability of year 1 by approximately 5%. This considerable increase in availability enabled EnergyAustralia to trade the battery more frequently and with greater confidence. The increased availability is due to the rectification of several technical issues identified over the first 12 months of operations.

Following the battery replacement program completed in Contract Year 2, it is anticipated that the SoC battery restriction will not likely be imposed in future, unless further directed to by the battery module manufacturer. The Ballarat System's availability without SoC restriction is expected to achieve approximately 99%.

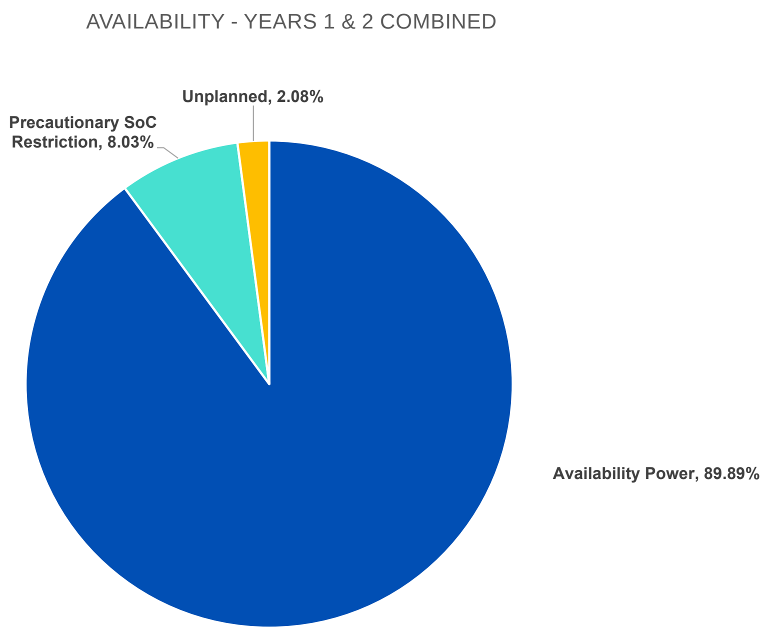

Figure 3 – Availability of Contract Year 1 & 2

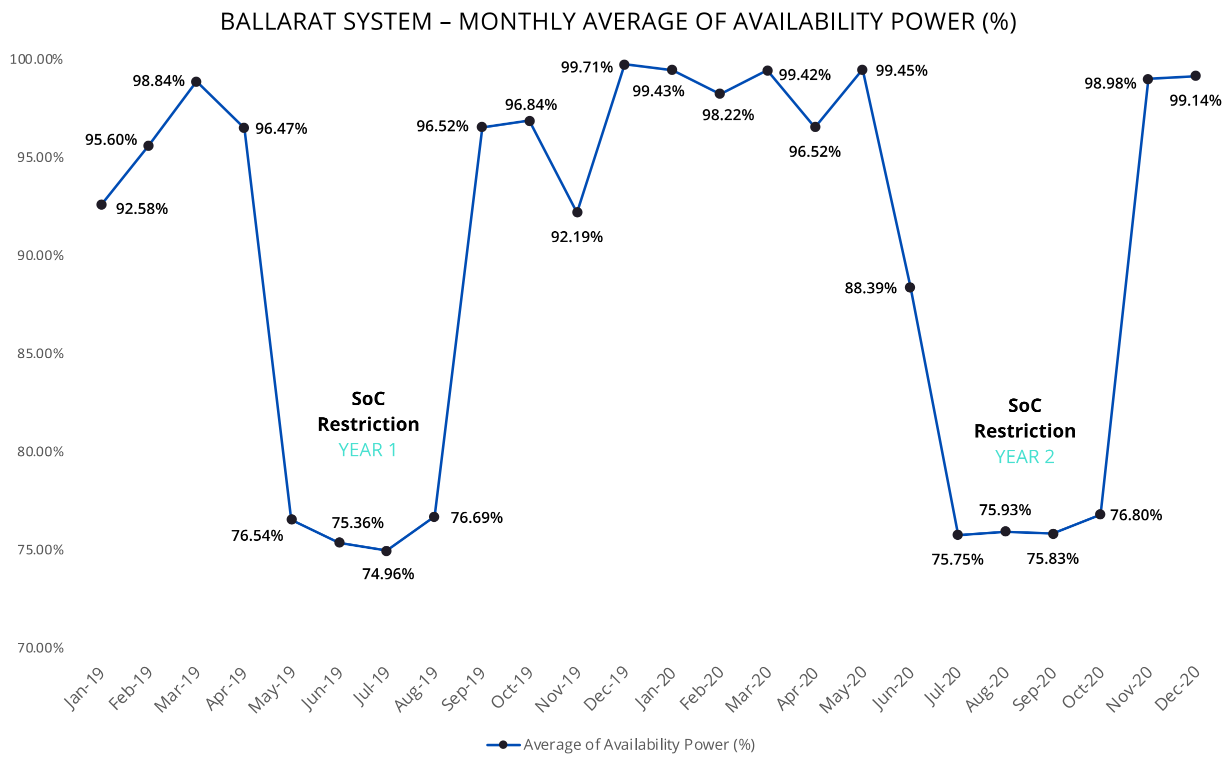

Figure 4 - Average Availability of Power

2.3 Operational Regimes

The overall bidding strategy for the Ballarat System is to optimise the earnings by utilising the registered markets (Energy/FCAS), while taking into account the contractual and technical limitations of the battery system.

System Limitations

A key restriction of the System is an allowance of only 260 cycles/year with this reducing each year to maintain a 15-year performance guarantee. The initial view was to aim for 1 cycle per peak day within the Energy market, essentially charging from the grid during the low demand overnight periods and discharging when prices were the highest (over the evening peak). This typical charging profiles can be seen in Figure 5.

Another limitation was around the maximum of 14 continuous hours at a SoC above 50%. This meant that holding a high SoC between the low priced and high-priced period was on occasions unattainable, creating the requirement to dip below 50% SoC to reset this limitation. This can be seen in some of the profiles below with multiple intraday charge/discharge profiles and charge/discharge profiles occurring closer together. Also, by holding this high SOC level, it is challenging to not exceed the annual average SOC value of 41%. However, in both contract year 1 and 2, availability issues restricted the battery SOC to 75% which consequently assisted in maintaining the annual average within contractual limits.

Further to managing the SoC contractual requirements, EnergyAustralia aimed to restore the SoC overnight, setting up the bids to charge across the 0200-0600 window unless the forecasts indicated a lower price across the middle of the day due to excess renewables. This provides charge in the battery and the targeted volume of charge would depend on the price forecasts and trader insight into the market. On subdued days where large price variances are not forecast/expected then the SoC would remain at levels around 50% as to manage the contractual obligations. If large price variances were anticipated, a higher SoC would be targeted to increase capacity to discharge into higher priced periods.

Typical Profiles

As a result of system limitations and changing market conditions, there has been no single typical discharging/charging profile. Initially EnergyAustralia was seeking a return of >$50/MWh in arbitrage and were happy to cycle >1 time if the market provided opportunities knowing there will be days when prices would remain flat with no cycling required. A good reflection of this can be seen early on with multiple profiles (refer to Figure 5) witnessed within Feb-Mar 2019 (30 min granularity).

Further to this, the typical day's cycle also depends highly upon the time of year and season with demand shapes varying and hence price highs/lows occurring at different times of the day. The dynamics are also changing as more renewable projects are implemented with high winds creating low price outcomes at all times of the day and high solar across the afternoons where typical daylight demands are at the lowest in winter and shoulder seasons.

Default offers can be used to an extent but due to daily variations in price and the added variable of managing the SoC, it is difficult to set-and-forget and fully optimise the return.

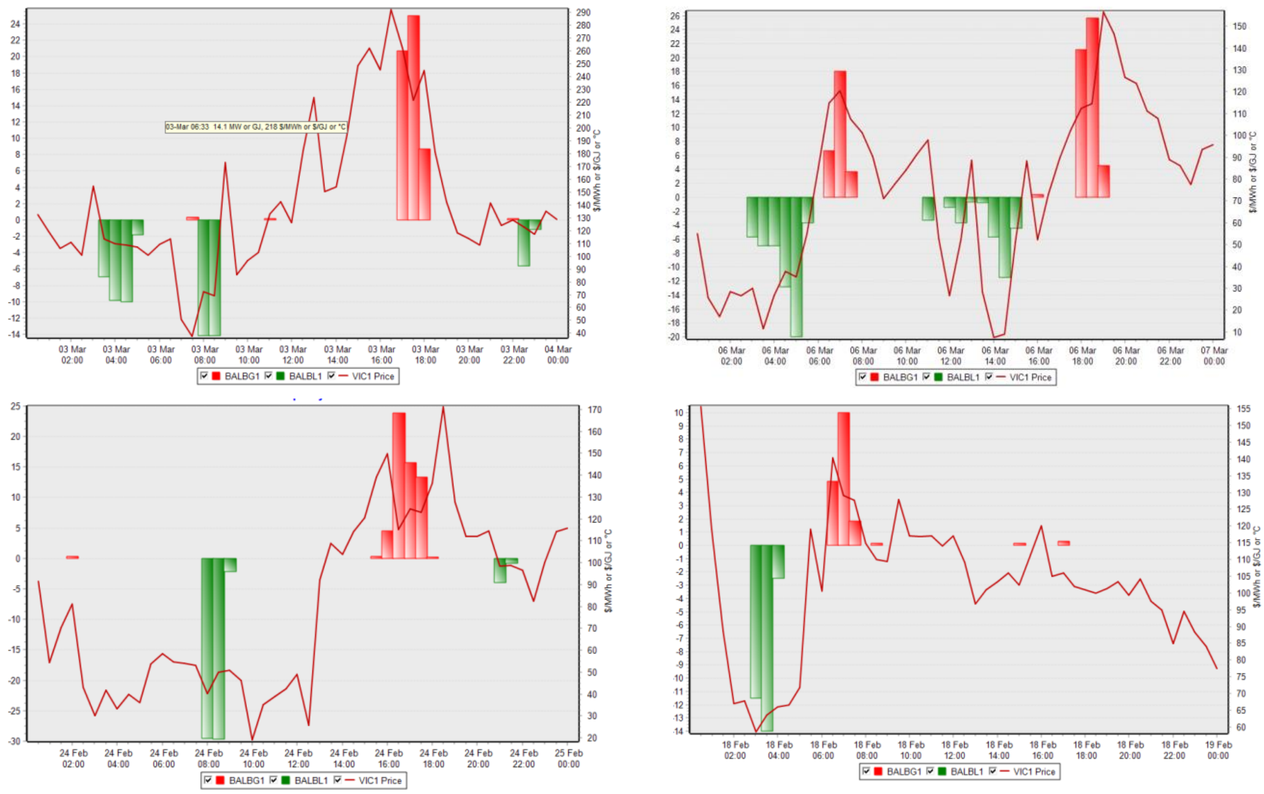

Figure 5 - Charging/Discharging Profiles - Feb-Mar '19

While the primary business case for EnergyAustralia was for energy arbitrage and capacity, the Ballarat System has out-performed expectations in the FCAS markets with the vast majority of revenue attributed to FCAS contingency service payments. The Ballarat System has been highly effective in the provision of FCAS services, which are critical in ensuring the stability of the system. Furthermore, the revenue generated indicates that a high-power (MW) and low-energy (MWhrs) system provides the greatest value.

Strategy Testing

From early on in its operations, the battery was utilised within the FCAS contingency markets. As mentioned, when enabled for the service (bid price at or above market price), the battery was only required to dispatch energy for ~10-20% of the enablement period, which allowed for incremental Energy market dispatch to increase the value of each cycle and maximise the revenue of the battery.

Due to the increase in the FCAS regulation requirement reaching 200MW (Raise) by late April (2.4 Key Events), the value in the Regulation market increased. With this increased dispatch in the FCAS markets and the reduced cycling due to less actual energy dispatched compared to enablement, the need to maintain a high SoC was reduced as it was more difficult to reduce the SoC to maintain contractual obligations without energy only bids to discharge which would most likely be at a sub-optimal price.

Within May 2019, a combination of Energy and FCAS bids were used to charge/discharge the battery providing ample SoC initially to dispatch into predominantly FCAS Raise services across the day. It can be noted that lower average energy volumes are dispatched across the day as discussed. Profiles can be seen below.

From late May 2019 several scenarios were tested utilising the Raise/Lower Regulation FCAS services on both the Generator and the Load DUID's. As we can see from the graphs below (5 min granularity) the energy requirements were quite demanding on the battery with both Raise/Lower FCAS services being enabled at varying times and multiple services being paid with the actual energy draw being rather small amount being shown in the SoC trace.

Note: Energy bids on the Load were used to supplement charging as to manage a higher SoC.

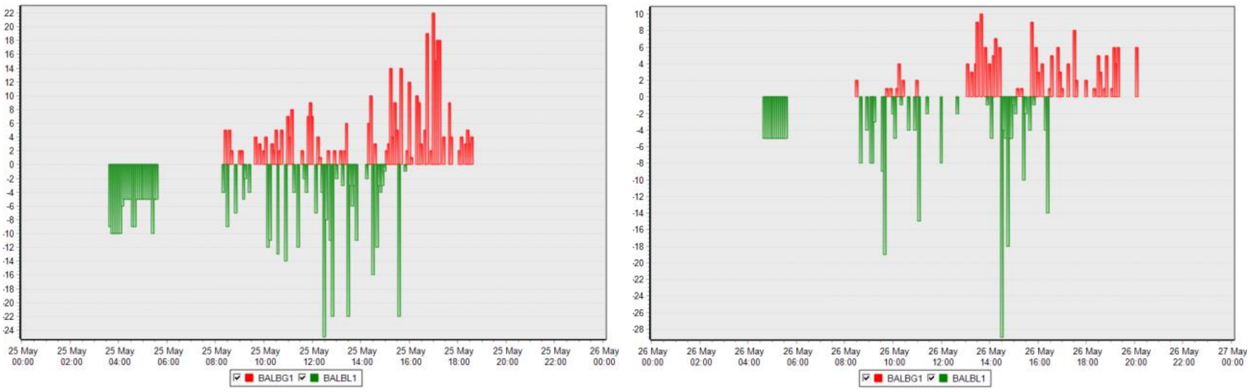

Figure 6 - Dispatch profiles - May 2019

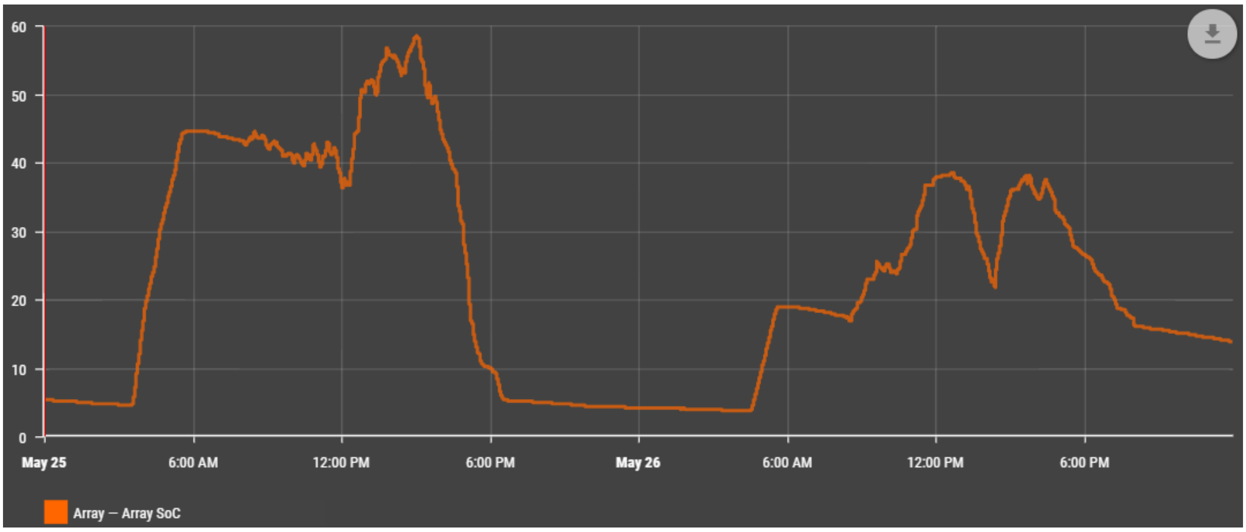

Figure *7* - Dispatch profile - May 2019

2.4 Key Events

Market Conditions

From March to June 2019, AEMO increased the minimum FCAS Regulation requirement from 130MW to 220MW and consequently Regulation FCAS prices increased creating further value within the FCAS markets as compared to the Energy market. It was noted that on average only ~10-20% of real energy was dispatched compared to the time the FCAS service(s) were required and hence the battery can be enabled for a longer duration while optimising cycles.

Lack Of Reserve (LOR) Response

The following table outlines the response of the Ballarat System during a Lack of Reserve notification from AEMO during the summer period. The Ballarat System was able to provide full capacity to the network during these periods.

Type of event	Date/Time	Description of event	Output of Ballarat System (MW)				
			Event start (0:00)	1st half-hour (0:30)	2nd half-hour (1:00)	3rd half-hour (1:30)	End of event (2:00)
Lack of Reserve (LOR2)	24/1/2019 – 16:00-18:00	AEMO calls on market to activate assets to provide adequate reserve capacity during tight market conditions	0.00	19.17	29.00	5.33	0.00
Lack of Reserve (LOR3)	25/1/2019 – 13:00-15:00	Customer load shedding in progress – Ballarat dispatched to inject power to meet peak need	0.00	3.33	23.00	23.00	0.00

Figure 8 - System response to Lack of Reserve

Q1 2019

The Ballarat System delivered significant revenue in Q1 driven by summer volatility. The Ballarat System's 1-hour duration means that it has limited firmness from a capacity perspective, which was highlighted by the sustained high price events on 24th January only capable of dispatching across a portion of the >5hr period above $10k/MWh. The Ballarat System is therefore only able to effectively assist with peak shaving.

Q1 2020

The Ballarat System has been highly effective in the provision of FCAS services, which are critical in ensuring the stability of the system. As was discussed earlier, the continued high penetration of renewable energy has seen a greater requirement for FCAS and therefore sustained high FCAS prices. The Ballarat System delivered more than half of its FCAS revenue in Q1, driven by summer volatility and corresponding high FCAS prices including the Vic-SA separation event on 31st January.

2.5 Operational Technical Challenges

2.5.1. Early Operations

Like other grid-connected resources and being the first standalone battery-based energy storage asset in the NEM, the Ballarat System required a period of time to work through a number or early issues. After commissioning, several operational issues relating to communication, software and additional features required for trading needed to be addressed. In expectation for early operation issues, the first five weeks of operations were excluded from any abatement schemes.

In the first two months, the initial post-commissioning issues related to data transfer between the on-site system controllers and remote energy management systems were the following:

- To ensure stable secure network connectivity to mitigate the risk of unplanned telecommunications service provider outages, additional backup connectivity was added onsite.
- To improve signalling, data transfer and visibility of the asset, so that EnergyAustralia traders can view all critical information required for trading. The technology partner has worked closely to improve signalling and integrate the Ballarat's Data Acquisition System with AusNet and EnergyAustralia systems.

The interface between the Ballarat System and AEMO's system required significant planning and testing for receiving dispatch targets as these signals need to be passed from the Ballarat System through AusNet's system through to AEMO's system. A complication that occurred during the debugging of incorrect signals was the involvement of multiple parties which introduced further complexity.

Another significant learning was the impact of parasitic loads during extended periods where the system was not in use. The preferred solution adopted to mitigate the draining of energy was to implement a software-based automatic adjustment of the SoC, to ensure the parasitic load did not interfere with daily operations.

Prior to establishing an Australian presence for technical support, there were initial challenges to resolve issues with the global team of the technology partner, which is based in the United States. The technology partner has since greatly expanded their local presence in Australia including a dedicated support team to improve responsiveness and communication.

2.5.2. State of Charge restrictions and battery replacement

In April 2019, following a safety event at a U.S-based storage facility, the Ballarat System received a notification by Fluence that recommended a precautionary and temporary modification (Modification) to system operational parameters, such that the battery modules in the system did not exceed a maximum SoC of 75%. This Modification was to remain in place until an investigation of the safety event could be undertaken, and a review of any impact to the Ballarat System was determined. The Modification was deemed a prudent safety measure and was enacted.

The impact of the Modification was reduced availability of the Ballarat System for trading proposes, however, several steps were then taken to enable the SoC restrictions to be removed in September 2019.

The following actions were taken prior to releasing the Modification:

1. Inspection of the Battery Modules - no abnormalities being detected
2. Software Enhancements - additional system control software to detect early deviations in battery cells and an update to the management of the SoC was added

3. Updated First Responder Training Material – to prevent injury to personnel, Fluence has updated the first responder training materials which also included a review and installation of onsite safety signage.
4. Review of Fire Suppression System – the review has determined the existing fire suppression system is fit for service.

In June 2020, AusNet received another similar notification from Fluence, for precautionary and temporary modification to system operation parameters, this time recommended by LG Chem (Battery OEM). The Modification was recommended following a recall of certain battery modules. This also resulted in the capacity and availability being constrained, impacting trading while the targeted battery module replacement work on the Ballarat System took place from October 2020, through to November 2020, after which the SoC restriction was removed, and the system returned to normal operations.

2.5.3. Contract Year 2 Performance Testing

Registered with AEMO as a 30 MW asset, the Ballarat System's health is assessed through performance testing at the commencement of each year. In Contract Year 2, due to the practical completion date (December 2018) failing within the constrained outage period over summer (December to April), the annual testing for contract year 2 was postponed by agreement of the Consortium until after the trading period.

As a result, the Ballarat System's performance was measured and evaluated after the defined performance guarantee date for Contract Year 2. Subsequently, module degradation during the intervening period may impact the measured performance value.

However, the Ballarat System did not experience any significant module degradation and pass all the following test:

- Deliver Cores Array Power
- Array Cores Energy
- Array Cores Round Trip Efficiency

To prevent this situation from arising again, thought needs to be given to ensure that performance testing does not line up with key trading periods.

2.5.4. Anti-islanding Protection Scheme

AEMO stipulates for the interface plant Protection and Control Requirements (PCR) that the Ballarat System is to be disconnected via the anti-islanding protection scheme in the event of a loss of phase on the 22kV balance of plant.

In Contract Year 2 the Ballarat System's availability was reduce by approximately 0.14% as AusNet Services experienced multiple unexpected trip events of the anti-islanding scheme. After investigation, this was found to be caused by high fault current disturbances on the upstream transmission network causing voltage instability for several cycles (milliseconds), resulting in the anti-islanding scheme inadvertently operating.

As a generation connection asset, changes to the protection and control scheme required the approval of AEMO. The proposed changes were then submitted by AusNet, reviewed, and approved by AEMO, and then implemented, rectifying this issue.

PART III
Market Services

3.1 General Financial Performance

EnergyAustralia is the registered market intermediary for the Ballarat System and is therefore responsible for the bidding of the battery system in the wholesale energy and ancillary services markets. The Ballarat System is registered as both a generator and a market load in the wholesale energy market and registered in all FCAS markets. While the primary business case for EnergyAustralia was for energy arbitrage and capacity, the Ballarat System has continued to generate greater revenues from FCAS markets.

The Ballarat System has been highly effective in the provision of FCAS services, which are critical in ensuring the stability of the system. Over the two-year knowledge sharing period, the continued high penetration of renewable energy has seen a greater requirement for FCAS and therefore sustained high FCAS prices. A summary of the financial performance of the Ballarat System during the first two years of operation, from a market perspective, is summarised in Table 6.

Table 4 – Financial Performance (figures in table provided in $000's)

BALLARAT	Q1-19	Q2-19	Q3-19	Q4-19	Q1-20	Q2-20	Q3-20	Q4-20	2019	2020
Pool Revenue	836	225	416	159	310	56	143	145	1,636	654
Charging Costs	-185	-173	-313	-114	-61	-32	-83	-79	-785	-255
FCAS Revenue	497	1,158	1,993	1,578	3,362	875	915	1,104	5,226	6,257
Market Fees	-1	-1	-4	-3	-2	-2	-3	-3	-8	-11
Net Revenue (pre-tax)	1,147	1,209	2,092	1,620	3,609	897	973	1,167	6,069	6,645

Note: excludes all fixed operating costs such as battery off-take, trading and IT overhead, compliance costs etc.

3.1.1. Ballarat System Value Streams

The overall bidding strategy for the Ballarat System is to optimise the earnings by participating in registered markets (Energy/FCAS), whilst giving consideration to the contractual and technical limitations of the battery system. The monthly revenue stack for the Ballarat System from January 2019 to December 2020 is shown in Figure 9. The performance of the Ballarat System in the FCAS markets, particularly the Contingency Raise FCAS and the Regulation Raise FCAS markets, has continued to exceed expectations in contract year two, despite the SoC operational restrictions.

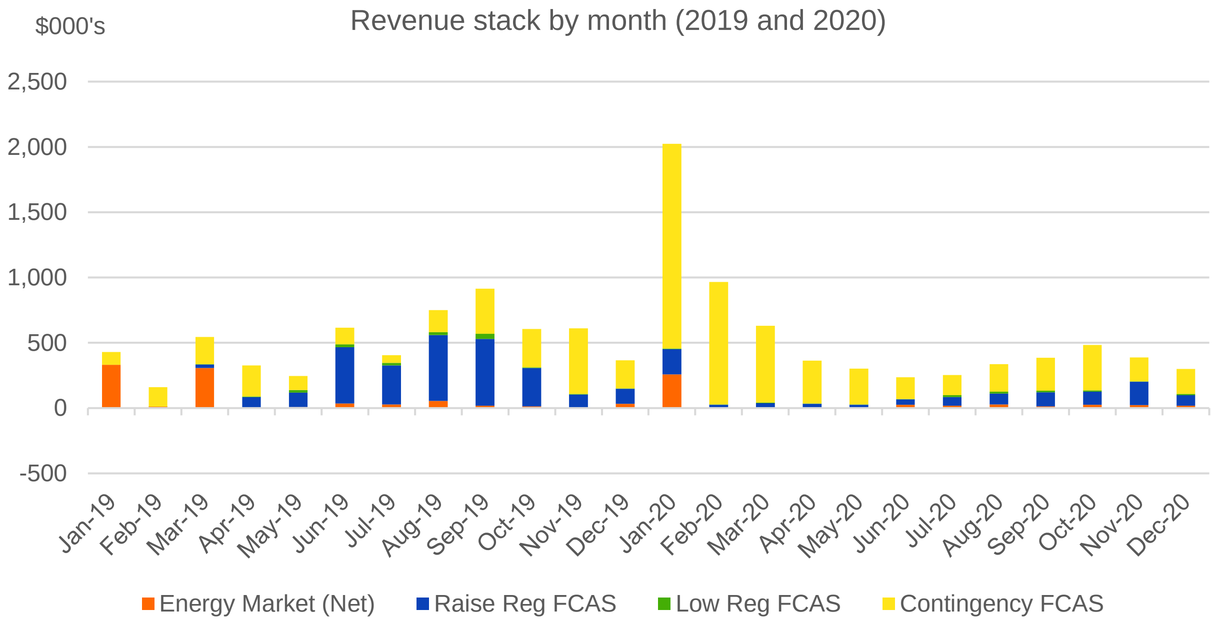

Figure 9 - Total Revenue Summary

3.1.2. Energy Arbitrage Outcomes

In the first two years of operation, the Ballarat System's dispatch was primarily optimised around FCAS markets given their higher prices. As a result, most revenues were generated from FCAS markets, and the spread between the average price paid and the average price received in the wholesale energy market was lower than if trading was optimised around wholesale energy market only. However, summer volatility in January 2019 and market events such as the VIC-SA separation on 31 January 2020 generated large price signals in the wholesale energy market, meaning dispatch is optimised to capture high wholesale energy prices, as illustrated in Figure 10.

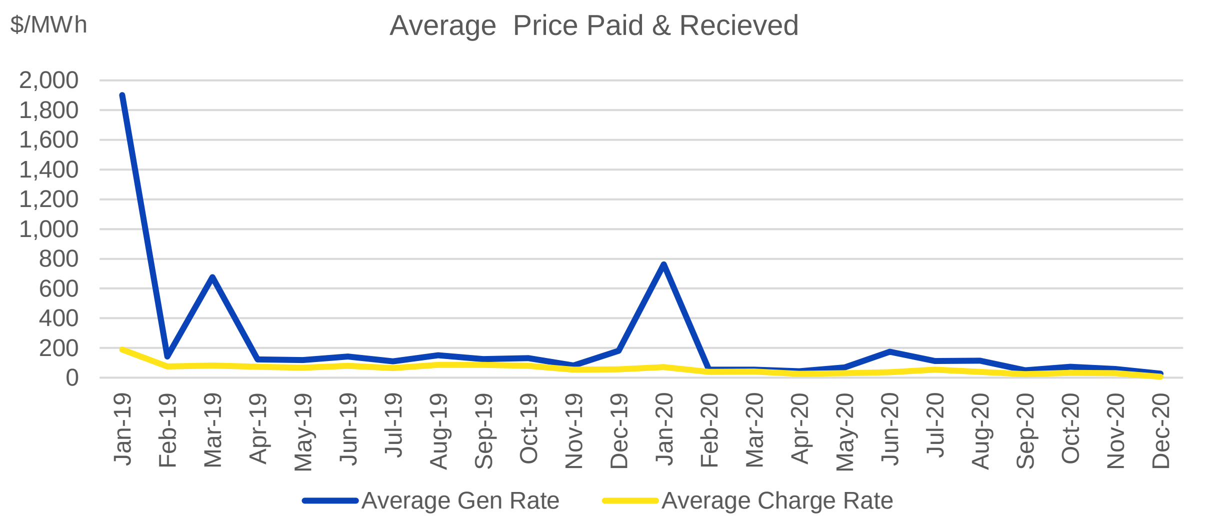

Figure 10 - Average Price Paid & Received

In general, over the two year period, generation and discharging volumes are higher during shoulder seasons when planned outages are often scheduled and therefore, less baseload plants are available to provide ancillary and energy services, increasing the utilisation of storage assets.

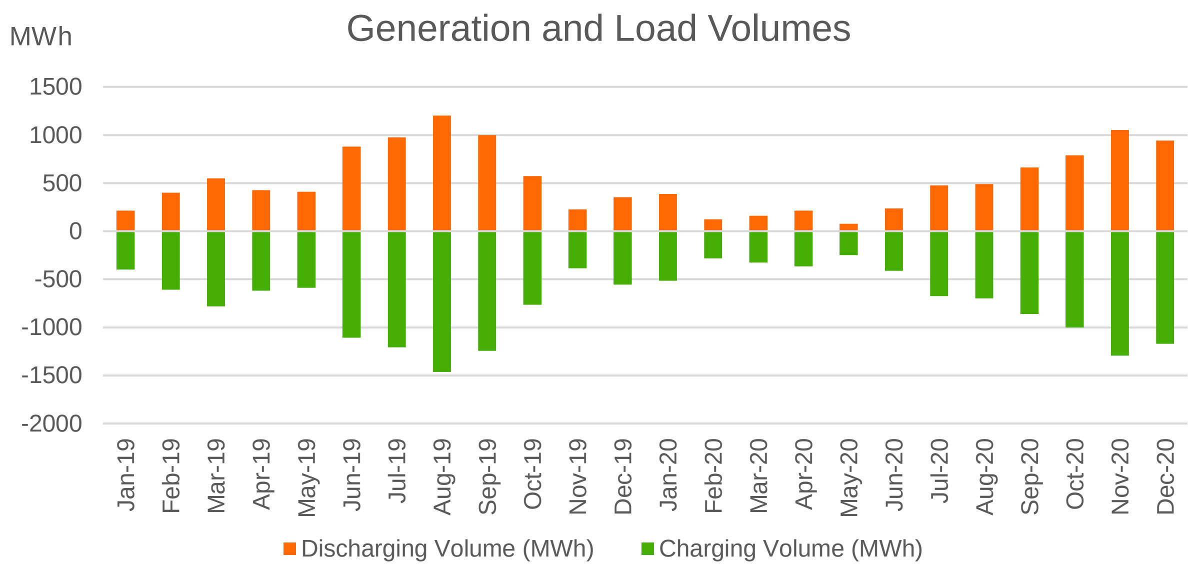

Figure 11 - Generation and Load Volumes (MWh)

3.1.3. FCAS Services Outcomes

The Ballarat System has performed extremely well in both the regulation and contingency FCAS markets over both contract years one and two. The Ballarat System delivered around 90% of its revenue from FCAS over the period. Of the FCAS revenue, raise regulation account for ~30%, contingency raise services around ~65% (5 seconds, 60 seconds and 5 minutes) and the remainder a combination of lower regulation and lower contingency services.

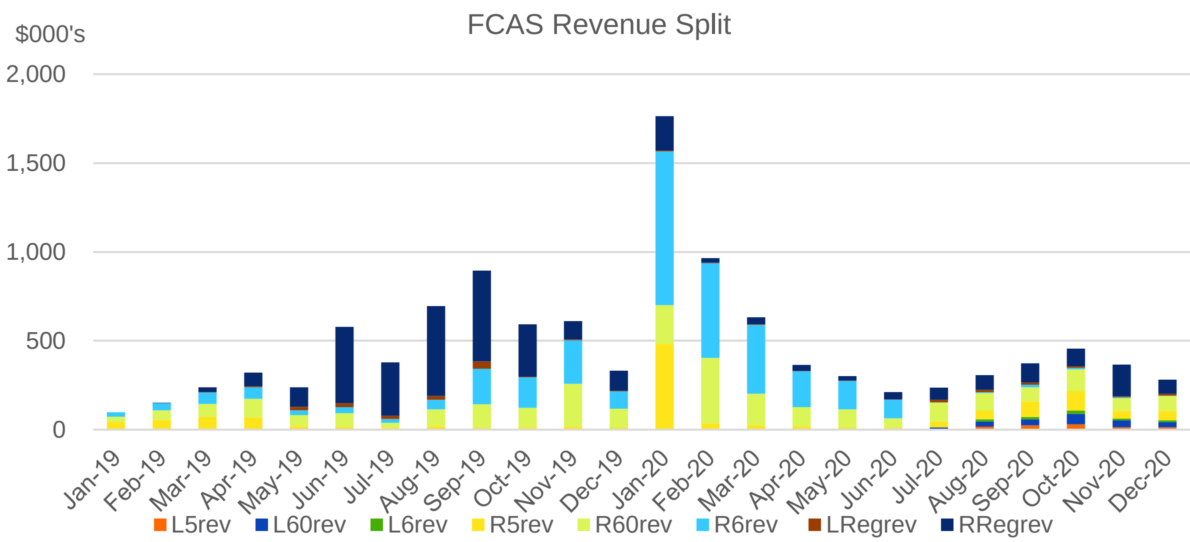

Figure 12 - FCAS revenue by market

3.2 Initial Business Case Comparison

A comparison of the business case of the Ballarat System will be different for each party in the Consortium. While return on investment is a factor, this was not the driving force behind AusNet's participation in the project. As the asset owner, and a network infrastructure business, AusNet took on the physical asset risks of owning and operating the battery asset, however contracting market facing risks to EnergyAustralia. In this structure, AusNet receives a fixed annual payment for providing battery services. This means any upside, downside, and regulatory risk, in access to market-based revenues are received by EnergyAustralia, whereas any asset and technology risks are born by AusNet, who in-turn pass some of these risks onto the technology provider Fluence. This is important context when reflecting on how the project has performed with respect to the original business case, as it will be different for each party.

From AusNet's perspective, the business case to date has met expectations. Contracted revenues have been received from EnergyAustralia as per the Battery Storage Services Agreement, the maintenance contract with Fluence has performed (and costed) as much as expected. Importantly, AusNet has benefited from the learnings regarding design, integration, operations and other aspects of the project which has given the business the confidence to proceed with an improved understanding of the risk on those future projects.

From EnergyAustralia's perspective, the business case to date has exceeded expectations, primarily driven market revenues being greater than the contracted cost for the battery services. As noted in this report, this is largely driven by FCAS market revenues in the first two years of operation exceeding expectations. However, we note that the business case for this project (and for most battery assets) is based on longer time horizons (10 plus years), so whilst it is positive that the project is generating positive financial returns in the first two years of operation, there is still the risk that market revenues fall for the remainder of the contract period. As such, the true business case performance can only be assessed at the end of the contracted period. From a learnings perspective, the Ballarat System has been critical to improving EnergyAustralia's understanding of battery projects, from both a market and physical perspective, and helped inform our approach to future battery developments.

From Fluence's perspective, the Ballarat System was a key market entry project for the business into Australia, and like AusNet and EnergyAustralia. A significant part of the business case was the learnings generated by being a part of one of the first large-scale battery systems built in Australia, as well as showcasing the flexibility and adaptability of battery-based assets in the NEM, as indicated in the previous Network Revenue Opportunities report. In general, the business case for Fluence met expectations and more importantly has provided a key platform to build on for future battery storage projects in Australia and the region as the first standalone energy storage system in Australia and the first connected at the transmission level.

Part V: Lessons Learned

4.1 Conclusion

The Ballarat System provided the Consortium with many key learnings and valuable lessons about the current state of battery technology and the consideration as an industry that need to be evaluated when undertaking a battery project.

As developers of this battery project some key general lessons learned are:

- Placement of the battery in the network is critical, as providing a network support service in addition to trading will increase the feasibility of the battery;
- The applications the battery is intended to provide. whether for arbitrage, FCAS or network support services, need to be factored into the initial design of the battery system to ensure it has the right capacity and flexibility in its cycling conditions; and
- Regulatory support is required to ensure batteries can provide and be compensated for a wider variety of services.

Moreover, from a trading perspective some key lessons learned are:

- If cycling limitations exist, then it is possible to maximise/extend a cycle by operating in the FCAS markets as well as the energy market;
- To date, based on the recent pricing, EnergyAustralia has had a bias towards FCAS markets compared to Energy utilisation (however several markets can be provided concurrently as paid for enablement without actual energy use).
- For the moment, from a trading perspective, Higher Capacity (MW) batteries are more advantageous compared to a higher Energy (MWh) battery with the ability to capture the low/high prices at a higher volume and a shorter timeframe. Higher MWs also have more value in the FCAS markets.
- Trading has required additional data points to be captured to allow for further analysis, use in alerting tools, business rule validations and API calls.
- Default offers can be used to an extent but due to daily variations in price it is difficult to set and forget and fully optimise the return. The added variable is managing the SoC to optimise depending on market outcomes.

Furthermore, while the FCAS market revenues have exceed expectations in contract year 1 & 2, it is unclear whether the prices for this ancillary service will remain at current levels. The uncertainty of FCAS market revenue is compounded by the;

- integration of more renewable energy generation increasing the share of renewable energy in the energy mix
- deployment of other battery projects across Victoria
- varying quantities of FCAS contingency and regulation required
- reforms to the regional procurement of FCAS
- introduction of the Primary Frequency Response requirement; and
- the introduction of the 2 second FCAS markets

The full effects of these factors have yet to be seen on the FCAS market price and therefore further research on these factors on the FCAS market should be a topic of further discussion.

While increases in market revenues and/or market reforms to improve price signals for battery investment will help battery business cases, it is likely that further significant build out of battery assets will also require capital and operation cost reductions. Future investigation and research needs to be conducted to determine the barriers to cost reductions and the steps all these groups can take to ensure that that cost saving for battery technology continues.

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