Operations Report #1

2020/ARP013 Transgrid Wallgrove Grid Battery

27 December 2021 - 21 June 2022

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The purpose of this document (Report) is to provide a summary of the first six-month period of operation of the Wallgrove Grid Battery.

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This Project received funding from ARENA as part of ARENA's Advancing Renewables Program and from the NSW Government Emerging Energy program.

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Acknowledgements.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program and was proudly supported by the NSW Government, Emerging Energy program.

Acknowledgement of Country.

In the spirit of reconciliation Lumea acknowledges the Traditional Custodians of the lands where we work, the lands we travel through and the places in which we live.

We pay respects to the people and the Elders past, present and emerging and celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the lands and waters of NSW.

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Contents.

1. Acronyms

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AGC	Automatic generation control
ARENA	Australian Renewable Energy Agency
BESS	Battery energy storage system
cFCAS	Contingency frequency control ancillary services
DI	Dispatch interval
FCAS	Frequency control ancillary services
HMI	Human machine interface
LSBS	Large scale battery storage
MLF	Marginal loss factor
MMS	Market Management System
NEM	National electricity market
NMI	National metering identifier
NP Cap	Nameplate capacity
OEM	Original equipment manufacturer
PoE	Probability of exceedance
PPC	Power plant controller
RoCoF	Rate of change of frequency
RRP	Regional Reference Price
RTAC	Real-time automation controller
RTE	Round trip efficiency
SCADA	Supervisory Control and Data Acquisition
SoC	State of charge
TNSP	Transmission network service provider
UPS	Uninterruptible power supply
UTC	Coordinated Universal Time
VMM	Virtual Machine Mode
WGB	Wallgrove Grid Battery

This Report summarises the operations of the Wallgrove Grid Battery (WGB) in its first six-month period of operation, from 22 December 2021 to 21 June 2022.

The WGB is a 50MW/75MWh (1.5-hour duration) battery energy storage system (BESS) located adjacent to the Transgrid Sydney West 330/132kV substation (Wallgrove) in Eastern Creek, NSW. The WGB tests how well a battery can deliver services that will be needed to stabilise the grid through Australia's energy transition to a low-carbon market. It also operates commercially, Iberdrola Australia controls the battery's dispatch to participate in the frequency control ancillary services (FCAS) and wholesale energy markets.

Approximately 1,040 work hours occurred onsite during the first six months of operations. There were no safety or environmental issues onsite.

The operation of the WGB in the energy and FCAS markets aligns with Iberdrola Australia's historical experiences in operating the Lake Bonney BESS in South Australia. The revenues earned by the WGB in the reporting period were highest during the extended market volatility experienced between April and June. During this time there were more energy revenue opportunities from discharging the battery into extreme high-price intervals. This contrasted with the comparatively low revenues earned by the battery from January to March, when high generator availability and limited peak demand (both due to lower maximum temperatures) caused limited market volatility and subsequently reduced revenue opportunities.

Photo 1 – Wallgrove Grid Battery and Sydney West 330/132kV substation aerial view

3.1. Purpose of Report

This Report covers the operational learnings over the first six-month period of operations for the WGB.

This Report focuses on the following areas:

- Analysis of charging behaviour, including participation in different applications (eg wholesale energy market, contingency FCAS, regulation FCAS etc)
- Technical performance such as round-trip efficiency, degradation, auxiliary power usage, equipment availability
- Financial performance (from the market participant's perspective) including a breakdown of revenue in each application, impact of loss factors, impact of curtailment, and any other factors materially impacting financial performance
- Safety and environmental performance
- Discussion on impact of any regulatory changes and any other emerging challenges and opportunities;
- Unexpected costs and potential new revenue opportunities (if any), and detail of challenges associated with accessing new revenue opportunities
- A discussion on the benefits and challenges of other innovative elements, including any other innovative elements requested by ARENA.

As Virtual Machine Mode (VMM) has not been enabled at this point, this report does not cover the following areas:

- Commentary and assessment of the project's ongoing performance with respect to the testing plan (for synthetic inertia), such as how the WGB has performed during system disturbances
- An overview of data analysed and observations during the relevant operation period (as specified in the testing plan) including:
  - Results and any key insights and learnings
  - Broader implications for the National Electricity Market (NEM), such as the role of batteries versus synchronous condensers.

Observations and learnings on VMM operations will be covered in subsequent operations reports.

3.2. Distribution of Report

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

The intended audience of this document includes:

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

3.3. Knowledge Sharing Plan

This document represents one of the deliverables under the knowledge sharing plan that forms part of the funding agreement between Transgrid and ARENA. All documentation associated with the Knowledge Sharing Program for the Project will be available from Transgrid's Wallgrove Grid Battery project website.

The knowledge sharing deliverables completed to date are shown in Table 1.

Deliverable	Responsibility
Arena 15 min project survey	Quarterly
Lesson learnt report #1	Submitted May 2021
Lessons learnt report #2	Submitted January 2022
Stakeholder reference group meetings	SRG meeting #1 03/02/2021 SRG Meeting #2 19/10/2021
Attendance at webinar or workshop	ARENA smart inverters webinar participation / presentation 27/05/2021 Presentation in ARENA grid forming / advanced inverters webinar 09/08/2022
Project website	Accessible via: https://www.transgrid.com.au/projects-innovation/wallgrove-grid-battery

Table 1 Knowledge sharing deliverables

Photo 1 Wallgrove Grid Battery looking towards Sydney West substation

Transgrid

Lumea

4.1. About Transgrid

Transgrid operates and manages the high-voltage electricity transmission network in NSW and the ACT, connecting generators, distributors and major end users. The Transgrid network is the backbone of the NEM, enabling energy trading between Australia's three largest states along the east coast and supporting the competitive wholesale electricity market.

4.2. About Lumea

Lumea is a renewable energy infrastructure, telecommunications, and energy services business. We operate in contestable markets across the NEM and are the largest connector of renewable generation in Australia to date. Our mission is to help bring 40GW of renewable energy to market by 2030. We will do this by capitalising on our skills, expertise and heritage as part of the Transgrid Group to help generators, large load customers and governments realise their own clean energy ambitions. Lumea is also proud to be developing its own innovative projects across a variety of new energy assets and services, as well as establishing a pipeline of grid-scale batteries.

4.3. Project Context

Australia's energy system transition to distributed renewable energy is expected to accelerate in order to reach the net zero emissions targets announced by both Federal and State governments. This means the continuing reduction of coal-fired generation, with AEMO's 2022 Integrated System Plan (ISP) forecasting 14 GW reduction in the NEM by 2030 under the step change scenario[1].

The increase in renewable energy generation and withdrawal of synchronous generation from coal-fired generators creates technical challenges, which impact the reliability and stability of the network. Following the retirements of Liddell, Vales Point, Eraring and Bayswater Power Stations, the inertia level in NSW is unlikely to meet the double contingency secure planning inertia level of 15,000 MWs for about 93 per cent of the time[2].

BESS are increasingly recognised as potential solutions to those network challenges, as well as providing storage capacity for renewable generation. AEMO anticipates that by 2050, 16GW of storage will be provided by utility-scale batteries and pumped hydro storage[3]. Furthermore, modelling indicates significant savings for NSW electricity customers from deploying BESS instead of traditional synchronous condensers to perform inertia services.

Transgrid expects that an inertia gap will be declared in NSW as existing sources of inertia, predominantly coal-fired generators, are progressively withdrawn from the market. In preparation for this event, Transgrid is investigating alternative technology solutions to establish technically and commercially viable, lower-cost solutions to address the inertia gap, including its first hybrid grid-scale battery – the Wallgrove Grid Battery.

1 AEMO ISP June 2022
2 Transgrid Transmission Annual Planning Report 2022, p101
3 AEMO ISP June 2022

4.4. Overview of Wallgrove Grid Battery Project

The WGB is a 50MW/75MWh (1.5-hour duration) grid-scale lithium-ion Tesla battery. It is the first large-scale grid battery in NSW and the third[4] large-scale grid battery demonstration of synthetic inertia in the National Electricity Market (NEM). Located at Wallgrove, the WGB is a pilot demonstration of the viability of synthetic inertia from a battery to maintain frequency stability on the network. The WGB is also enabling Iberdrola Australia to control dispatch and participate commercially in the frequency control ancillary services (FCAS) and wholesale energy markets.

The WGB was undertaken as an innovation pilot, to build battery expertise, and to support the development of more efficient synthetic inertia technologies in different locations on the grid, including areas of higher population density. The model combines funding to maximise battery utilisation for network and commercial purposes.

The WGB can provide both network services (including inertia and fast frequency response) and market services (including energy and FCAS), and accesses corresponding regulated and unregulated revenue streams in a hybrid commercial model. Less than 5 per cent of energy storage capacity is reserved for the provision of network services. The project enables the TNSP, Transgrid, to explore this approach as a credible option to address the forecast inertia shortfall in NSW/ACT following the retirements of numerous coal-fired generation plants, including Liddell, Eraring and Vales Point Power Stations, and enable the NSW Government's plan for a reliable, affordable and sustainable electricity future that supports a growing economy.

Information is being shared as part of the trial. This information sharing will support future projects and improve understanding of battery technology as a low-cost and technically viable solution to the emerging challenges created by the transformation of the generation sector. The project also demonstrates a revenue stack and commercial arrangements that provide grid benefits cost-effectively for consumers.

The trial will provide valuable technical information about the actual operation of the WGB, including how often it will be needed for fast frequency response and how much electricity it is able to store and dispatch under different conditions, relative to commercial demands.

As more wind and solar energy sources replace fossil fuel generation, less mechanical inertia is available on the grid, removing a natural stability buffer in the case of a grid disturbance. As these fossil fuel generators retire from the NEM, alternative solutions are needed to ensure this stability remains. The WGB will demonstrate the use of Tesla's Virtual Machine Mode (VMM) to address these stability challenges by virtually emulating mechanical inertia. While commercial operations continue, the WGB is currently undergoing final technical assessments in conjunction with AEMO prior to enabling VMM.

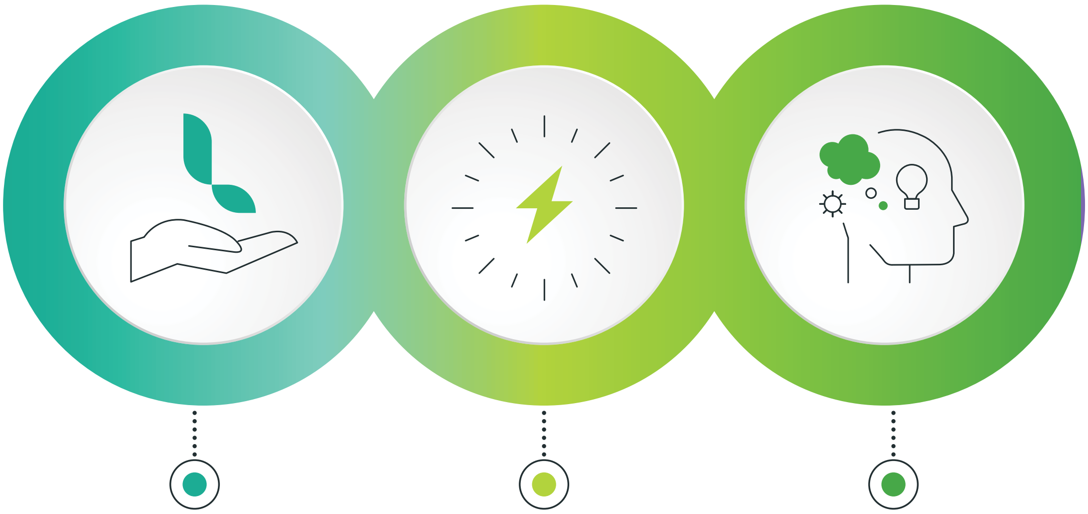
The WGB received funding from ARENA's Advancing Renewables Program and the NSW Government as part of the Emerging Energy Program. The WGB has been constructed, registered, tested and commissioned successfully, and commenced Commercial Operations in December 2021. To 1 September 2022 it has exported 18.4GWh[5] of energy, supplying the energy needs of 4,850 NSW households[6].

4 Wallgrove is the third BESS in the NEM to demonstrate synthetic inertia. ESCRI (30MW) and Hornsdale Expansion (150MW) are the first and second.

5 https://www.transgrid.com.au/media/i25ndg0l/2022-08-02-operations-data-2021-12-23-to-2022-07-13.csv and https://www.transgrid.com.au/media/hfbcd3s4/07092022-operations-data-14072022-to-01092022.csv

6 https://cdn.ausgrid.com.au/-/media/Documents/Data-to-share/Average-electricity-use/Ausgrid-average-electricity-consumption-by-LGA-2021-pdf

Project Benefits



Enhanced reliability

The battery will provide a new source of system stability services.

More affordable power

Finding lowest-cost ways to maintain frequency, while also increasing the supply of dispatchable power to the market, puts downward pressure on energy bills.

New knowledge

The trial will provide valuable technical and commercial insights which will be shared across the energy industry – helping to identify the lowest cost technology for future network needs.

4.5. Key Project Objectives

The project's objectives, as agreed with NSW Government and ARENA

ARENA	NSW Government
Supporting technical innovation: Improved understanding of the ability of FFR services and Tesla's Virtual Machine Mode to substitute for inertia and help meet Transgrid's requirement to manage RoCoF in NSW with transferable learnings across the National Electricity Market. Support inclusion of LSBS projects in the Recipient's regulatory submission: The Project will help support Transgrid's vision to include ~240 MW of LSBS projects in its revenue submission to the AER for the upcoming regulatory period (2023/24 to 2027/28). New commercialisation pathway: The Project will contribute to the development of a new commercialisation pathway for LSBS by leveraging regulated network expenditure to provide a clear pathway to commercialisation for LSBS. Improving supply chains: Relatively few LSBS projects have been installed. Supporting LSBS will improve supply chains and reduce costs for OEMs and balance of plant providers.	Enhance system reliability and security in NSW by operating in the wholesale energy and frequency control ancillary services markets in the NEM, as well as provide inertia support activities including fast frequency response and virtual inertia; Promote competition through its contracting arrangement with Iberdrola Australia which will operate the project to firm variable renewable energy generation in NSW to supply retail customers Promote diversification of electricity supply in the NSW region of the NEM by deploying a lithium-ion battery system in the NEM that is dispatchable and capable of firming variable renewable energy generation Assist in the operation of a low emissions NSW electricity system by firming Iberdrola Australia's variable renewable energy output from their portfolio Provide value to NSW and the NEM by sharing key learnings to reduce the risk and encourage further investment in utility scale battery energy storage systems in NSW.

4.6. Technical Overview

The key technical operating parameters of the WGB are shown in Table 2.

Technical parameter	Summary
Registered discharge power capacity	50 MW (at 132kV connection point)
Registered charge power capacity	47 MW (at 132kV connection point)
Nameplate storage capacity	75 MWh (at 132kV connection point)
Number of megapacks	36
System voltages	132 / 33 / 0.518 / 0.4 kV
Balance of plant	60 MVA 132/33kV power transformer 9 x 33/0.518/0.518kV coupling transformers ABB SafePlus gas-insulated compact switchgear 500kVA 33/0.400 kV auxiliary transformer 75kVA isolation transformer for street supply
Point of connection	Sydney West 330/132kV substation – Feeder Bay 2X
Metering point location	Sydney West 330/132kV substation – Feeder Bay 2X
Network connection	132kV
Substation	Sydney West 330/132kV substation
National Metering Identifiers	**Wallgrove Battery 132kV Revenue:** NTTTW0ZQ90 for Import B1 (Generation) NTTTW0ZQ91 for export E1 (Consumption) **Wallgrove Battery 132kV Check** NTTTW0ZQ95

Table 2 Key technical parameters

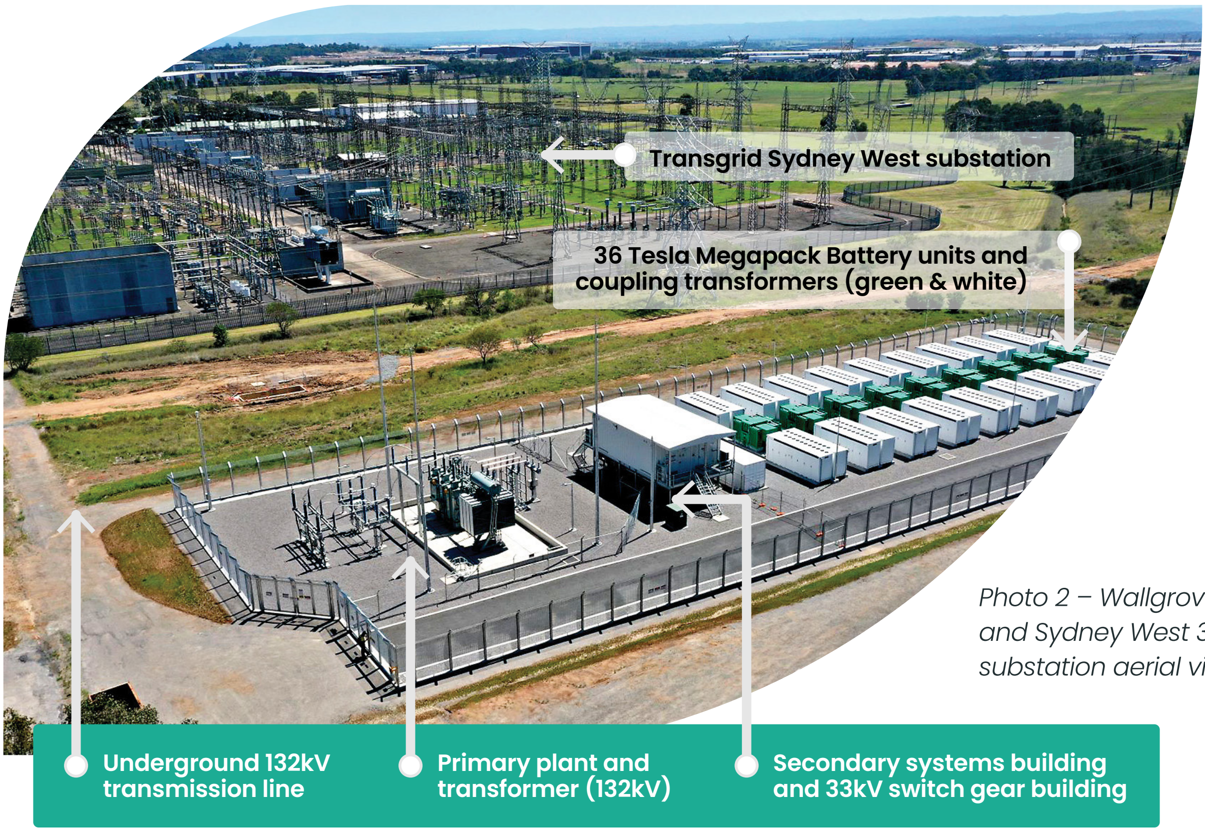


Photo 2 – Wallgrove Grid battery and Sydney West 330/132kV substation aerial view

5.1. Energy Market Participation

The following factors constrain a battery's participation in the energy market, and should be considered when assessing the WGB's energy market participation:

- The regulation and contingency FCAS markets still represent the largest share of revenue available to a battery. Whenever a battery is dispatched to provide FCAS, its ability to provide energy is constrained
- The energy storage capacity of a battery constrains its short-term operations
- The cycling limitations of a battery (ie the number of times the battery can be charged and discharged per year) constrains its long-term operations.

5.2. Capacity Factor

The energy-only capacity factor[7] of the WGB throughout the reporting period is shown in Table 3, alongside the percentage of intervals in which the WGB is active in a discharge (energy, raise regulation and raise contingency) or charge (energy, lower regulation and lower contingency) market.

		Energy-only capacity factor (%)	Active intervals (%)
Q4 CY2022 (from 23 December 2021)	Discharge	0.02	99.03
	Charge	2.10	99.83
Q1 CY2022 (January to March 2022)	Discharge	0.97	97.80
	Charge	2.48	98.11
Q2 CY2022 (April to June 2022)	Discharge	3.22	91.98
	Charge	9.29	92.21

Table 3 – WGB energy-only capacity factor and active intervals in the reporting period

There was a clear variance in the behaviour of the WGB in Q1 and Q2. The lower energy-only capacity factors seen in Q1 is indicative of limited arbitrage opportunities, which reduced the incentive to cycle the battery. In comparison, the energy-only capacity factors seen in Q2 highlight the increased arbitrage opportunities observed during this time, particularly in the weeks leading up to the market suspension of the NEM on 15 June 2022. While not presented in Table 3, in the two weeks prior to the market suspension the discharge capacity factor of the WGB was higher still at 4.34 per cent, which equates to 52MWh discharged per day on average (before considering the impacts of FCAS enablement).

The reduced active intervals seen in this quarter were driven by two main events (refer to Sections 6.5 and 6.6 for further information on outages):

- A five-day maintenance period in May, which lowered the active intervals for this month to 84 per cent.
- Reduced participation in June during the market suspension. The BESS was unable to charge to increase its storage levels to the required amounts for market participation due to the over-constrained dispatch price settling above the highest energy load bid that the BESS could provide ($15,100/MWh). This also contributed to the AGC outage discussed in Section 6.6.1.

7 Capacity factor represents the average generation (or consumption) of a power plant across a year as a percentage of its nameplate capacity. For example, a 100MW generator with a 50% capacity factor might have run at 100MW capacity for half a year, and 0MW for the remainder of the year; or at 50MW for the entire year.

5.3. Arbitrage Price Dynamics

Energy market revenue opportunities for the WGB are based upon the principle of arbitrage, being able to buy energy when prices are low (by charging) and/or selling this energy when prices are high (by discharging).

These dynamics should not be confused with the market conditions periodically observed during some periods of Q2 CY2022, where a high average price was observed, but with limited variation in price and therefore limited opportunity for the battery to arbitrage.

The key market factors that dictate the opportunities of the WGB in the energy market are shown in Table 4. These are the average, and the 50 per cent and 25 per cent probability of exceedance (PoE)[8] differences between the highest and lowest value dispatch interval (DI) each day.

	Average daily DI max/min difference ($/MWh)	50% PoE daily DI max/min difference ($/MWh)	25% PoE daily DI max/min difference ($/MWh)
December 2021	232.65	146.90	183.38
January 2022	158.04	130.02	223.60
February 2022	802.49	139.92	242.05
March 2022	506.04	227.38	257.22
April 2022	371.09	287.23	299.99
May 2022	2,795.86	407.55	1,197.28
June 2022	1,954.34	547.79	1,031.85

Table 4 - Market factors for consideration for an energy arbitrage strategy – dispatch intervals

The comparable values between the average and 50 per cent PoE daily DI differences highlight the volatility in the energy market in May and June. It should also be noted that these results only consider the highest and lowest value DI prices (settled over five-minute intervals). The price arbitrage opportunity for a battery will be somewhat less, depending on its storage duration.

This is an important metric for energy prices as the average value can be distorted by a minimal number of extreme pricing events. Under most circumstances the 50 per cent PoE is a much better indication of normal market conditions than the average value.

The revenue earned by a BESS from this price difference would be further eroded by round-trip efficiency losses and the potential marginal loss factor (MLF) difference between the generator and load portions of the BESS. However, for the WGB, given its strong connection point into the network, any MLF revenue adjustments are marginal with a FY2022 MLF of 1.0010 and 1.0009 for its generation and load components respectively.

5.4. Negative Price Opportunities

Negative price intervals are starting to become more regular in the energy market for the NSW region of the NEM, but these intervals are yet to represent a notable revenue opportunity for a battery to be paid to charge. Of the 236 negative intervals observed in the reporting period (0.43 per cent of all intervals), only eight of these intervals settled at a price below -$50/MWh.

8 Probability of Exceedance (PoE) is a statistical metric that describes the probability of a particular value being exceeded

5.5. Charging and Discharging Profiles

The charging and discharging behaviour of the WGB in its first two full quarters of operation is shown in Figure 1.

Figure 1 - Average daily charging profile for the WGB in the reporting period

Figure 2 - Average daily discharging profile for the WGB in the reporting period

The most notable difference in the charging and discharging profiles is observable in the morning. The concentration of charging in morning periods seen in Q1 CY2022 becomes more distributed throughout the middle of the day in Q2 2022. This aligns with the market dynamics, in which there were relatively more pronounced morning peaks in Q2 compared to Q1, which discourage charging due to the higher prices. When analysing the discharge profile of the battery, a higher portion of energy is discharged into these morning peak periods in Q2 2022, aligning with the increased economic opportunity of arbitrage.

5.6. Provision of Regulation FCAS

The levels of regulation FCAS enabled for the WGB throughout the reporting period is displayed in Figure 3.

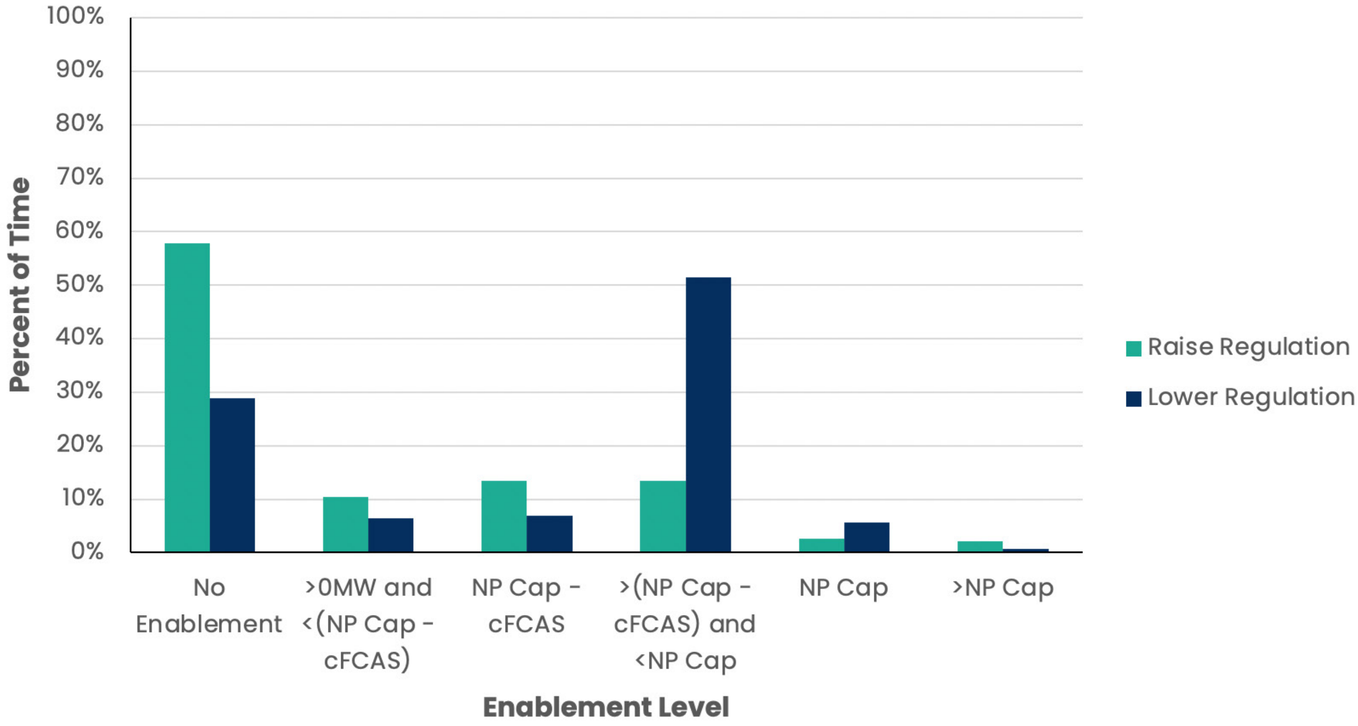


Figure 3 - Regulation FCAS market enablement in reporting period

The regulation FCAS enablement levels are reported across six categories, which reflect the provision of co-optimised services (ie contingency FCAS and energy). These categories are explained in Table 5.

The WGB can provide three different services: energy, regulation FCAS, and contingency FCAS. These services are co-optimised, which means that they can be provided simultaneously, but they have to share the WGB's nameplate capacity. The WGB has a nameplate discharge capacity of 50MW. However, whenever the WGB is fully enabled for contingency raise, 26MW of this nameplate discharge capacity must be reserved as headroom. This leaves only 24MW for the provision of regulating raise FCAS and energy (in the same DI). Conversely, enabling the WGB for more than 24MW of regulating raise impacts the amount of contingency raise that can be enabled in the same interval. Dispatch for energy (discharge) further reduces the amount of regulating raise and/or contingency raise that can be provided in the same interval, whereas dispatch for energy (charge) would increase it.

The WGB is registered for 50MW in the regulating raise market, and 47MW in the regulating lower market, reflecting the WGB's asymmetric nameplate capacities (50MW discharge / 47MW charge).

Fully enabling the WGB for contingency FCAS requires 26MW of capacity in both directions. This means that whenever the WGB is providing the maximum possible amount of contingency FCAS, it can simultaneously provide:

- 50MW nameplate discharge capacity – 26MW required for cFCAS = 24MW of regulating raise
- 47MW nameplate charge capacity – 26MW required for cFCAS = 21MW of regulating lower

	Raise regulation	Lower regulation	Comment
No enablement	0MW	0MW	
>0MW and <(NP Cap – cFCAS)	1 to 23MW	1 to 20MW	
NP Cap - cFCAS	24MW	21MW	No impact on contingency FCAS. This indicates the WGB is providing the maximum possible amount of contingency FCAS (26MW), and is using all its leftover capacity to provide regulation FCAS.
>(NP Cap – cFCAS) and <NP Cap	25 to 49MW	22 to 47MW	Some impact on contingency FCAS. This indicates the WGB is providing less contingency FCAS in order to provide more regulation FCAS.
NP Cap	50MW	47MW	WGB is only providing regulation FCAS (not providing any contingency FCAS or energy). This indicates the WGB has stopped providing contingency FCAS and is using all its capacity to provide regulation FCAS.
>NP Cap	>50MW	>47MW	WGB is providing regulation FCAS and energy in the opposite direction. This indicates the WGB has been dispatched to fully prioritise regulation FCAS over contingency FCAS.

Table 5 - Regulation FCAS category capacities

The findings align with Iberdrola Australia's expectation from the enablement distribution seen with Lake Bonney BESS (owned and operated by Iberdrola Australia).

Similar characteristics include:

- Lower regulation FCAS is enabled far more frequently than the raise service
- The even distribution of enablement of raise regulation FCAS across the different categories, with an increased economic opportunity to provide raise contingency FCAS limiting the percentage of raise regulation FCAS provided above the NP Cap – contingency frequency control ancillary services (cFCAS) threshold in comparison to lower regulation FCAS.

One notable difference is the increased percentage of lower regulation FCAS enablement within the NP Cap – cFCAS category. Historically at the Lake Bonney BESS, this percentage of enablement would be seen in the NP Cap category instead.

The cause of this differential was a rounding issue resulting in only 46MW of the 47MW in nameplate charge capacity being indicated as available to bid into the markets. This led to frequent enablement of lower regulation FCAS at 46MW prior to a software update undertaken in May 2022 (56.73p er cent of all intervals prior to May 2022 saw lower regulation FCAS enablement at 46MW – consistent with expectations for enablement levels in the NP Cap category).

Following this update the battery system began to report 47MW of charge capacity available to bid into the market. Subsequent enablement of lower regulation FCAS at the full 47MW level increased to 29.5 per cent throughout June 2022.

5.7. Provision of Contingency FCAS

The levels of contingency FCAS enablement for the WGB for the state reporting period are displayed below.

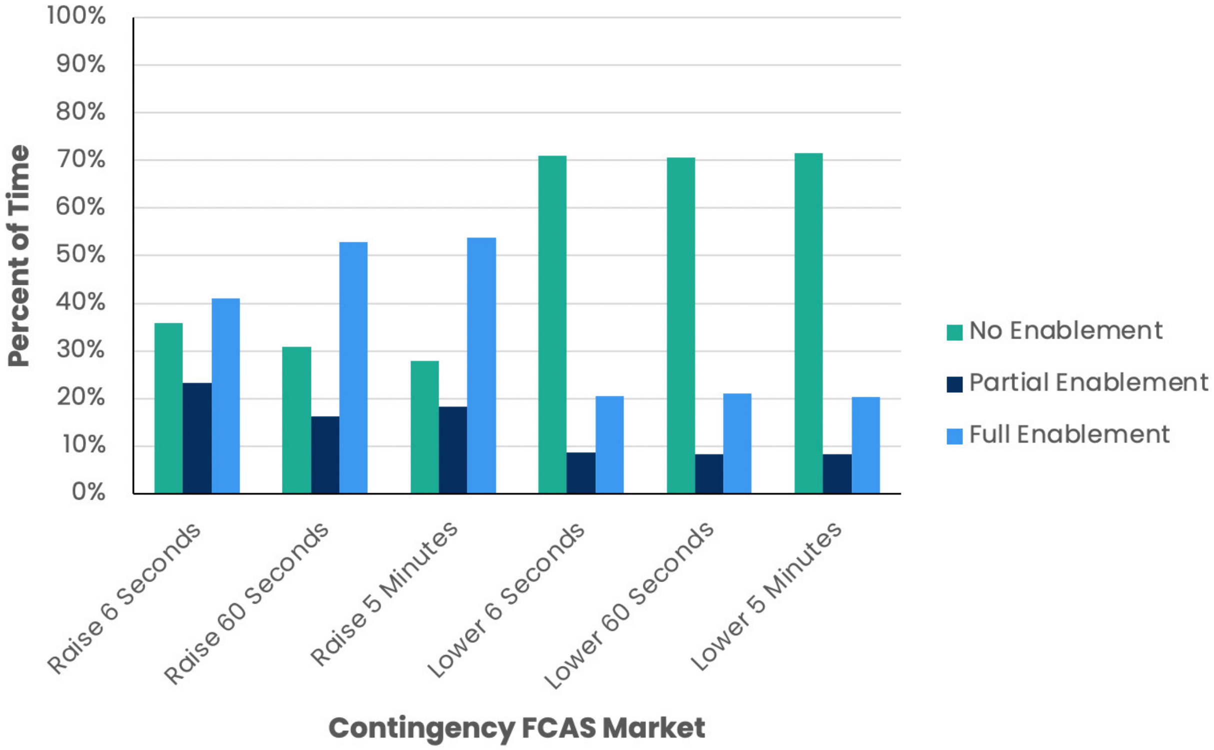


Figure 4 - Contingency FCAS market enablement in state reporting period

Similar to the regulation FCAS enablement distributions, the contingency FCAS enablement in Figure 4 is generally in line with expectations from previous experience with Lake Bonney BESS. In particular, the high percentage of non-enablement periods for the lower contingency FCAS markets aligns with the operation of Lake Bonney BESS. It is explained by the corresponding higher enablement in the lower regulation FCAS market which were found to be more lucrative.

One point of difference to note is the increased percentages of partial enablement seen across all three of the raise contingency FCAS markets. While there is no single factor for these increases, the proportion of partial enablement higher than 70 per cent of the full enablement value for each respective market is above 10 per cent of all intervals.

5.8. Extreme Market Prices Capture Rates

5.8.1 Energy Market

The average energy response of the WGB during extreme energy price events within the reporting period is shown in Table 6.

	Dispatch interval ranges	# of periods	Average energy response (MW)
Q4 CY2021 (from 23 December 2021)	DI above $1,000/MWh	1	-16.00
	DI below $-500/MWh	0	n/a
Q1 CY2022 (January to March 2022)	DI above $1,000/MWh	4	34.25
	DI below $-500/MWh	2	-46.00
Q2 CY2022 (April to June 2022)	DI above $1,000/MWh	193	19.54
	DI below $-500/MWh	0	n/a

Table 6 - Wallgrove Grid Battery response during extreme energy price events

When considering the energy response, it is important to consider the context of the market conditions or co-optimisation with the regulation FCAS markets. For instance, charging events just above the $1,000/MWh threshold make sense when in preparation for the price to reach the market price cap ($15,100/MWh), as was the case in Q2.

Co-optimisation occurs where charging the battery allows the WGB to provide additional raise regulation FCAS. While the average response when charging during these high-price intervals was 28.4MW, the corresponding average raise regulation FCAS enablement was 50.2MW (ie more than the WGB's nameplate discharge capacity).

The average energy responses in Table 6 are consistent with the performance of Lake Bonney BESS.

5.8.2 FCAS Markets

The average market enablement of the WGB during extreme FCAS price events within the reporting period is shown in Table 7.

	DIs above $1,000/MW/h	Average enablement (% of registered capacity)
Raise 6 Seconds	11	23.87%
Raise 60 Seconds	1	100.00%
Raise 5 Minutes	0	n/a
Raise regulation	11	15.54%*
Lower 6 Seconds	0	n/a
Lower 60 Seconds	0	n/a
Lower 5 Minutes	0	n/a
Lower regulation	0	n/a

Table 7 - WGB enablement during extreme FCAS price events

** Registered capacity of regulation services is 50MW for the purpose of these calculations*

When analysing the average energy response, it is problematic to interpret the average enablement without considering the full co-optimisation of the battery. The reduced enablement in the raise 6 seconds and raise regulation markets occurred within a period of one hour. During this time the battery was instead used to discharge into the energy markets to cover off Iberdrola Australia's portfolio risk.

6.1. Round-Trip Efficiency

Round-trip efficiency (RTE) is the percentage of the energy put into the battery that can be retrieved. It is calculated as the ratio of energy exported / energy imported through a given point (eg the inverter terminals, or the grid connection point), over a given duration. The RTE of the WGB throughout this time is shown in Table 8.

The WGB is connected directly to the transmission network, and the RTE is measured at the transmission network connection point. The RTE therefore includes losses in the 132/33kV power transformer.

Method	Round trip efficiency at 132kV transmission network connection point (%)
Operational performance estimate from 23 December 2021 to 23 June 2022	83.2%

Table 8 - Round trip efficiency performance

6.2. Operational Performance Estimate

The operational RTE performance can be estimated as follows:

RTE = (total energy exported - start state of charge (SoC) + end SoC) / total energy imported

For the period starting 23/12/2021 10:00am UTC+10 and ending 23/06/2022 10:00am UTC+10[9]:

- Start SoC = 48 MWh
- End SoC = 25 MWh
- Total energy exported = 12,562 MWh
- Total energy imported = 15,074 MWh
- RTE = (12,562 – 48 + 25) / 15,074 = 83.2 per cent

Note that the difference between the RTE test result vs operational RTE performance estimate reflects the difference between test conditions vs operational conditions, rather than any material deterioration in RTE performance since commissioning. For example, auxiliary and standby losses have a much bigger impact on RTE when ambient conditions during operation are outside the range of standard test conditions.

6.3. Degradation

An official storage capacity test is conducted at the end of every contract year. We will report on degradation after the next test is conducted on 23 December 2022.

6.4. Auxiliary Power Usage

Auxiliary power usage is not recorded. It was estimated to be 7.6kVA by observing the auxiliary power distribution board power meters over a one-hour period. The measurements were taken during the day and therefore do not account for yard lighting. The auxiliary power distribution board supplies power to the following:

- BESS protection, control, and communication systems
- Secondary systems – uninterruptible power supply (UPS)
- BESS security systems
- Switch room and auxiliary services building and light power and fire detection systems
- Power transformer auxiliary supply
- Yard light and power.

9 This data is available at https://www.transgrid.com.au/projects-innovation/wallgrove-grid-battery

6.5. Availability

Availability performance for the first six months of operation was:

Available 96.1%

Unavailable due to planned outages 2.8% (inclusive of one-off 132kV defect rectification and SCADA and protection relay setting changes)

Unavailable due to unplanned outages 1.1% (noting that remote access was not available for the site during this period).

6.5.1 Planned Outages

The planned outages that occurred during the reporting period are shown in Table 9.

Planned outage date	Works occurred
19 January 2022	132kV cable defect rectification
16-20 May 2022	SCADA and protection relay setting changes

Table 9 – Planned outages

6.5.2 Unplanned Outages

The unplanned outages that have occurred during the reporting period are shown in Table 10.

Unplanned outage date	outage
11 - 12 January 2022	Network disturbance and isolation of the WGB. Technician attended site to reclose circuit breakers
15 June 2022	WGB unable to recharge due to AGC outage

Table 10 – Unplanned outages

6.6. Other Technical Performance Issues After Commercial Operations

6.6.1 Automatic Generation Control Outages

The operation of the WGB is highly dependent on communications systems, including AEMO's automatic generation control (AGC) signal which controls the dispatch of the battery in the energy and regulation FCAS markets.

In June 2022, during the height of the energy crisis, Iberdrola Australia was required to discharge the WGB during the market suspension but then it was unable re-charge it due to the over-constrained dispatch price settling above the highest energy load bid that the BESS could provide ($15,100/MWh). As a result, the WGB was discharged to a very low state of charge (SoC).

This caused the WGB site controller to disable AGC mode. This was by design, to prevent the WGB from being dispatched when it did not have sufficient stored energy to participate in the market. Unfortunately, this also made it impossible for Iberdrola Australia to re-charge the battery via the normal dispatch process (ie via AGC), meaning the only way to re-charge was via manual dispatch.

The over-constrained dispatch price subsequently remained above $15,100/MWh, which prevented Iberdrola Australia from recharging the battery, despite the manual dispatch capability being made available.

The WGB eventually recharged itself through provision of contingency FCAS (which is always enabled, regardless of dispatch instructions or AGC) to a point where the site controller automatically re-enabled AGC mode.

The following lessons were learnt from this outage:

- BESS operators should consider the consequences of any control logic that disables AGC mode.
- Systems and processes for manual dispatch should be regularly reviewed and tested, to ensure that a BESS can continue operating with minimal disruption in the event of an AGC outage.

6.6.2 Arc Flash Risk

During the design of the WGB an arc flash risk was identified around the low-voltage circuit breaker panels. An arc flash is a sudden release of electrical energy that could cause human harm or damage to equipment. The risk was initially managed by implementing an exclusion zone whilst the WGB was energised. In May 2022, protection settings were changed to reduce the clearance time for arcing faults, which reduced the arc flash risk sufficiently that the exclusion zone was no longer required.

Arc flash risk should be considered for all electrical installations integrating into the grid (including battery projects), due to the possibility of high fault levels in medium and low-voltage parts of the system.

6.6.3 SCADA Changes

Transgrid has initiated changes relating to the SCADA system since commencing commercial operations. To perform the necessary works the battery had to be taken out of service. These works were conducted under a continuous outage and implemented at the same time as the protection relay changes, thereby minimising the impact to the customer.

Commentary and data presented in this section are from Iberdrola Australia's perspective, unless noted otherwise.

7.1. Market Revenue

7.1.1 Data Sources

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

Energy revenue = MWh exported * Energy Regional Reference Price (RRP) * Marginal Loss Factor (MLF)

(with MWh imported reflecting a negative MWh export)

FCAS revenue = MW enabled * FCAS RRP / 12

MWh imported/exported is derived from nemweb.com.au/Reports/Current/Causer_Pays/

FCAS enablement is obtained from nemweb.com.au/Reports/Current/Next_Day_Dispatch/

Prices are obtained from nemweb.com.au/Reports/Current/Public_Prices/

MLFs are obtained from nemweb.com.au/Reports/Current/Marginal_Loss_Factors/

7.1.2 Market Revenue by Month

The revenue earned by the WGB for each month in Figure 5.

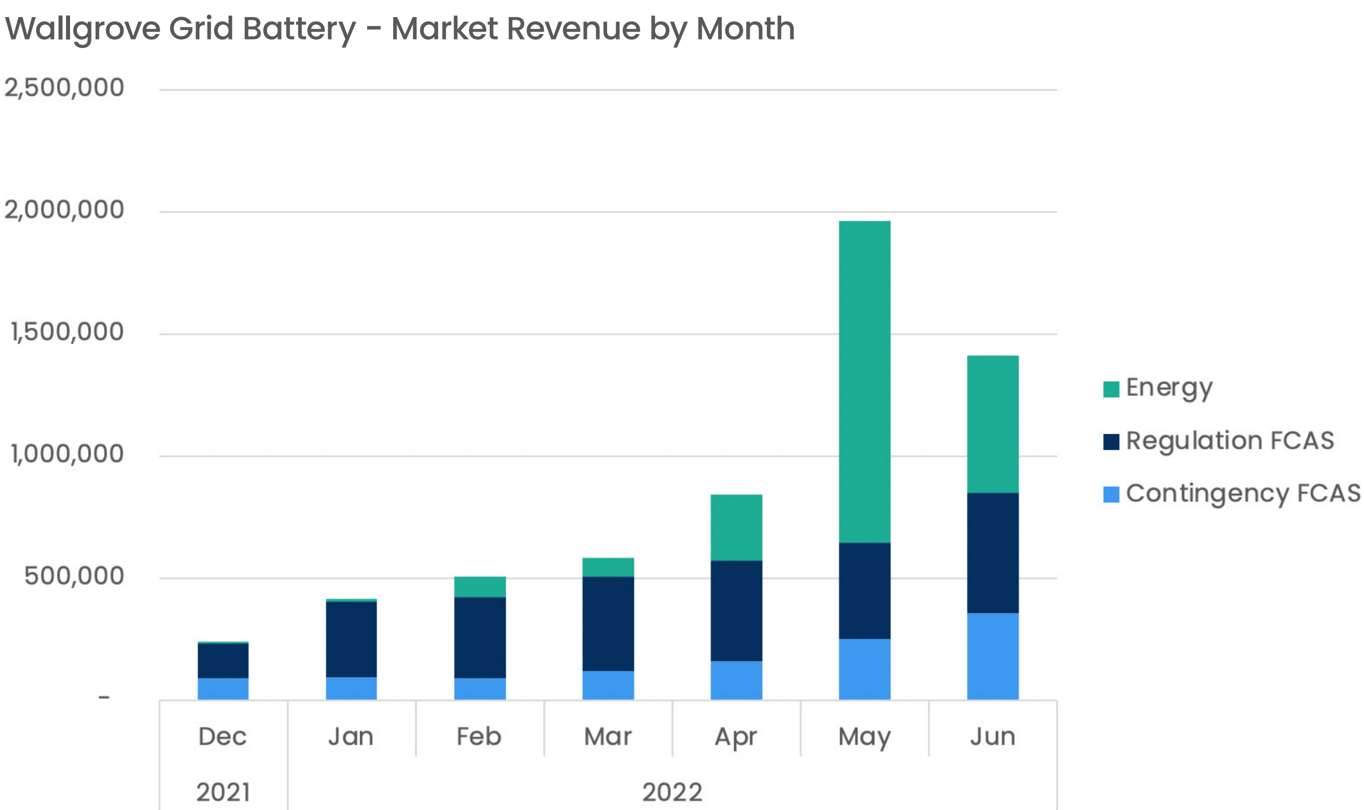


Figure 5 - Market revenue by month

The battery commenced commercial operations on 23 December 2021, so the reduced revenues seen in December 2021 are not indicative of the limited revenue opportunities experienced in the following summer quarter from January to March.

The revenue results achieved in January to March 2022 are similar to market conditions previously seen during summer quarters when milder temperature conditions were experienced. This led to reduced peak load demands in the system, as well as high generator availability during these peak periods. Lower demand and increased generator availability both suppress price volatility in the energy markets, reducing arbitrage opportunities for the battery. Revenues earned in the FCAS markets during this quarter were consistent, although average prices in the contingency FCAS markets were lower than recent historical prices – again partially driven by the high availability of generation in the system.

In comparison to the summer quarter, market conditions from April to June saw extreme volatility driven by a number of factors (discussed further in Section 7.2.3). This led to an uplift in revenues across all markets. This was most notable in the energy markets where a number of high-priced events occurred in the leadup to the market suspension in May and early June. This allowed the WGB to discharge energy and capture prices up to $15,100/MWh. As noted above, FCAS market volatility is typically aligned with energy market volatility. A corresponding uplift in market prices and subsequent revenue was also experienced in these months.

7.1.3 Market Revenue by Application

The revenue earned by the WGB for each application is shown in Figure 6.

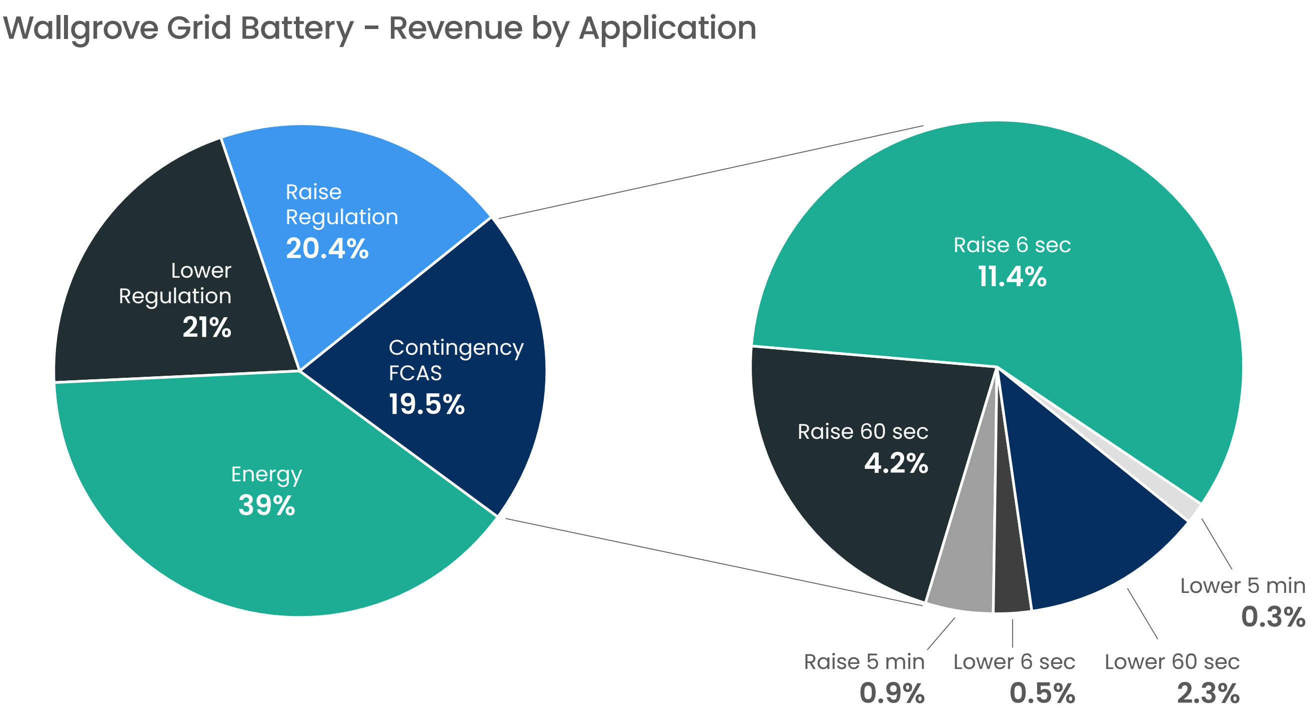


Figure 6 - Market revenue by application - 23 December 2021 to 30 June 2022

For comparison, typical revenue distribution for Iberdrola Australia's Lake Bonney BESS during its two years of operation were about 25 per cent of revenue from the energy market, 45 per cent from the regulation FCAS market, and 30 per cent from the contingency FCAS market.

The proportion of revenues earned by the WGB in the energy market for the reporting period is therefore higher than historical expectations. However, it is indicative of the extreme, sustained volatility seen in the energy market over that time. For reference, the proportion of energy revenue earned by Lake Bonney BESS, as a percentage of its total earnings in the first half of 2022, was approximately 50 per cent (even higher than the WGB's proportion of earnings).

While this period also aligns with operations under the energy market's new five-minute settlement structure, the higher proportion of energy revenue seen in this reporting period was mainly driven through consistent market volatility and not directly attributable to the new settlement rules.

7.2. Factors Materially Affecting Market Revenues

7.2.1 Marginal Loss Factors (MLFs)

Given that the WGB is adjacent to the regional reference node of the NSW region, long-term stability of the generator and load MLFs were expected to have negligible impact on the revenues generated by the battery in the energy market. This was reflected in the first two MLFs reported for financial years 2022 and 2023 shown in Table 11.

Financial year	WALGRVG1 (generator)	WALGRVL1 (load)
2021-22	1.0011	1.0010
2022-23	1.0010	1.0009

Table 11 – MLF values for the Wallgrove Grid Battery

7.2.2 Curtailment Impacts

As with the MLFs for the WGB, the strong point of connection has limited any curtailment risks for the operations of the battery to date.

7.2.3 Market Suspension

In the second quarter of 2022 there were materially higher prices than any quarter previously seen in the NEM's operation. These high prices were driven by a combination of factors, including:

- a combination of planned and unplanned thermal plant outages
- lower than typical wind and solar output
- high commodity prices (driven by the war in Ukraine)
- major downstream hydro constraints.

On 11 June, Queensland was the first state to breach the cumulative price threshold and enter into the administered pricing period following sustained periods of pricing above $300/MWh and numerous extreme high price peaks. On 13 June, New South Wales, Victoria and South Australia followed suit.

AEMO imposed the $300/MWh price cap across all mainland regions. However, the underlying dispatch price remained at the market price cap of $15,100/MWh. Energy constrained generators such as the WGB took drastic measures to ensure they were not continuously dispatched and bid their availability out of the market. While the energy constrained generators bid out of the market, they made AEMO aware they were available for direction to run when the system needed it.

Other generators, who had a short run marginal cost greater than $300/MWh (due to the high underlying commodity prices) also bid their generation out of the market and available for direction, to ensure they were able to seek further compensation for the direct costs they took on to run.

AEMO noted publicly the high volume of generator directions it was giving, and with the administered pricing period not looking like it would end, AEMO took the significant step of suspending the market at 2pm on 15 June.

7.3 Future Revenue Opportunities

Iberdrola Australia continues to be an active participant in a number of rule change requests and market design proposals under consideration by the Australian Energy Market Commission (AEMC). These include the introduction of system security services that were previously identified as new market opportunities for dispatchable generators (and batteries in particular) such as the WGB.

The determination by the AEMC on the establishment of two new markets (the very fast raise contingency service and very fast lower contingency service) to deliver FFR services in the NEM is the first of these new markets to be realised, planned for October 2023.

7.3.1 Primary Frequency Response Incentive Arrangements

Iberdrola Australia also remains an engaged participant in the discussions around the future arrangements for the provision of primary frequency response and whether incentives should be established to encourage a market response. The WGB remains well positioned to participate flexibly for any future requirement or incentive regime.

7.3.2 System Security Services

A number of rule change requests for the introduction of new system security markets have been made to the AEMC, including:

- a FFR ancillary service market for raise and lower responses measured within a timeframe of 0.5-2 seconds from the frequency excursion event (completed – new FFR market commences October 2023)
- an operating reserve (OR) market for generators that can provide a dispatchable response within 30 minutes, with a 15-minute call time (draft determination due June 2023)
- a ramping service ancillary service market for raise and lower responses that operate over a 30-minute period (draft determination due June 2023)
- an inertia spot market that would replace the current mechanism whereby inertia is procured by TNSPs (pending initiation).

There should be no barriers for the WGB participating in these markets if/when they are established. The WGB would be able to provide the required responses within either short-term or medium-term timeframes (subject to operational state of charge limitations).

Major considerations for Iberdrola Australia utilising the WGB to participate in future markets such as these are the enablement constraints with other market services and the potential energy throughput due to enablement.

7.4 Unexpected Costs

Transgrid has incurred additional unexpected costs in the current reporting period due to the following items:

- Additional labour for SCADA changes for design and implementation
- Additional labour for to facilitate the required outages for protection changes
- Increased insurances cost due to the delay of issuing practical completion
- Unexpected costs increase due to complexity of remote maintenance connection and Transgrid cyber security integration requirements
- Additional personal protective equipment expenses due to the number of unexpected site visits from internal and external stakeholders.

Approximately 1,040 work hours occurred on site during the first six months of operations, as shown in Table 12. The total hours include both Transgrid and Tesla employees and subcontractors. No maintenance was conducted on the balance of plant which is to commence in the next period. The hours observed are higher than expected due to project defects being rectified and changes being implemented on site. Some maintenance of the Megapacks were conducted during this period.

Operational period	Approximate work hours onsite
22 December 2021 – 21 June 2022	1040

Table 12 – Work hours on site

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