Final Knowledge Sharing Report

CPEO | 190025 NSW Grid Battery

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.

Contents

1. Acronyms

AEMO	Australia Energy Market Operator
AER	Australian Energy Regulator
ARENA	Australian Renewables Energy Agency
BESS	Battery energy storage system
BOP	Balance of plant
CCTV	Closed circuit television cameras
COVID-19	Coronavirus disease
D&C	Design and construct
EPC	Engineering Procurement Construction
EP&A Act	Environmental Planning and Assessment Act
ESV	Energy Safe Victoria
FCAS	Frequency control ancillary services
FRT	Fault ride through
FFR	Fast frequency response
GPS	Generator performance standards
LSBS	Large scale battery storage
LVRT	Low voltage ride through
MW.s	Megawatt Seconds
NEM	National Electricity Market
NER	National Electricity Rules
NMI	National metering identifier
OEM	Original equipment manufacturer
PPC	Power plant controller
RoCoF	Rate of change of frequency
RTAC	Real-time automation controller
SCADA	Supervisory Control and Data Acquisition System
SVC	Static VAR Compensator
TNSP	Transmission network service provider
WGB	Wallgrove Grid Battery

2. Executive Summary

The Wallgrove Grid Battery (WGB) is a 50MW/75MWh grid-scale lithium-ion battery. Located at Wallgrove adjoining the Sydney West substation, it became the first large-scale grid battery in NSW when the project commenced commercial operations on 22 December 2021.

This Report provides general project information, including technical specifics, the commercial model and the commercial performance of the battery, and lessons that have been learned along the way. The Report focuses on how the WGB has moved the industry forward through the support of the NSW Government and ARENA.

The primary objective of the project was to support technical innovation by improving the understanding of how the selected Tesla technology could provide synthetic inertia to substitute for the inertia that would be leaving the system with the retirement of thermal generation, and to do so while in commercial operation. The synthetic inertia capabilities were enabled on 23 November 2022 and Transgrid is now able to observe how the battery performs through grid disturbance events.

3.1. Purpose of Report

This Report provides general information on the Project, analysis of market performance, and broad lessons learned and outcomes for the benefit of industry development.

3.2. Distribution of Report

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

The intended audience of this document includes:

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

Photo 1 – Wallgrove BESS looking towards Sydney West 330/132kV Substation

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. Lumea operates in contestable markets across the NEM and is the largest connector of renewable generation in Australia to date. Lumea's mission is to help bring 40 GW of renewable energy to market by 2030 using the 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 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

The energy transition creates technical challenges, such as ensuring the system has enough inertia. A stable and reliable network requires inertia to support the power system to resist changes in frequency. Traditionally, inertia is provided by synchronous generators, such as coal plants, but 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 level. One possible way to address this inertia shortfall is through the provision of synthetic inertia through BESS.

BESS are increasingly recognised as a potential solution to network challenges, with the additional benefit of providing storage capacity so the grid can access renewable generation when the sun isn't shining, and the wind isn't blowing. AEMO anticipates that by 2050, 14GW of storage will be provided by utility-scale batteries.

As existing sources of inertia, predominantly coal-fired generators, are progressively withdrawn from the market, Transgrid is investigating alternative technology solutions to establish the technical and commercial viability of lower-cost solutions to address the inertia gap, including its first hybrid grid-scale battery – the Wallgrove Grid Battery.

4.4. Overview of the Wallgrove Grid Battery Project

The WGB is a 50MW/75MWh (1.5-hour duration) grid-scale lithium-ion battery. It became the first large-scale grid battery in NSW. Located at Wallgrove, the WGB is a pilot demonstration of the viability of synthetic inertia from a battery to support frequency stability on the network. Iberdrola Australia controls dispatch of the WGB and participates 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 synthetic inertia technologies in different locations on the grid, including strong areas of the grid. Transgrid embarked on the WGB project to explore synthetic inertia using specialist firmware to mimic the "swing equation" that governs the rotor dynamics of a synchronous machine. This product is manufactured by Tesla and, when configured to deliver synthetic inertia, is described as operating in virtual machine mode (VMM).

The project commenced commercial operations in December 2021, and has operated with its synthetic inertia capability enabled since November 2022. The project has generated valuable technical information about how often it is needed for fast frequency response, how it performs as a source of inertia in the event of grid disturbance, and how much electricity it stores and dispatches under different conditions.

4.5. Key Project Objectives

ARENA	NSW Government
Supporting technical innovation: Improved understanding of the ability of Fast Frequency Response (FFR) services and Tesla's Virtual Machine Mode to substitute for inertia and help meet Transgrid's requirement to manage Rate of Change of Frequency (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 ~240MW 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, and providing 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 operating 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 Details

Table 1 – Key technical parameters

Deliverable	Responsibility
Nominal Discharge Power capacity	50 MW
Nominal Charge Power capacity	47 MW
Registered Storage capacity	75 MWh
Power capacity degradation	N/A
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 GIS RMU 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 Identifier Numbers	Wallgrove Battery 132kV Revenue: • NTTTW0ZQ90 for Import B1 (Generation) • NTTTW0ZQ91 for export E1 (Consumption) Wallgrove Battery 132kV Check • NTTTW0ZQ95

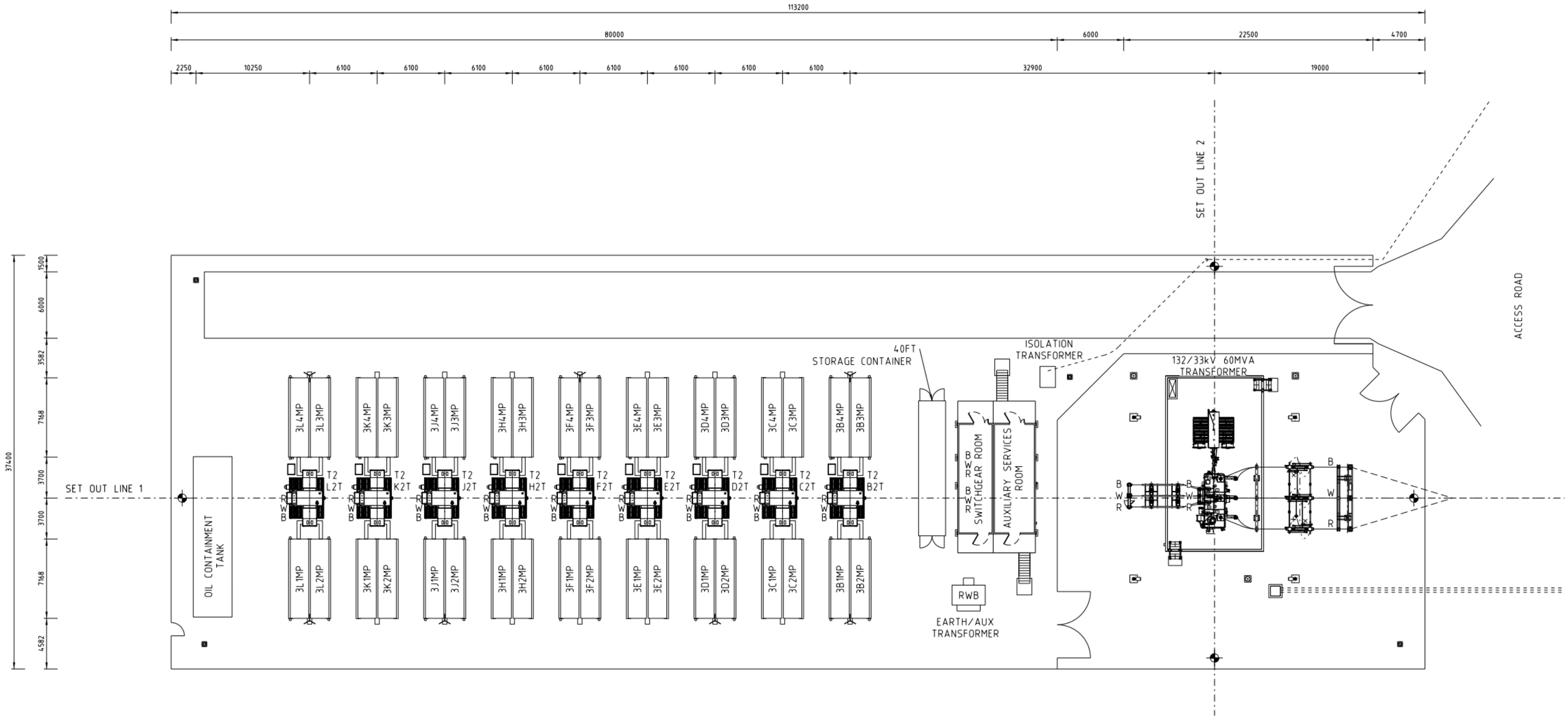


Figure 1 – Wallgrove Grid Battery General Arrangement

5.1. Overview

The WGB commercial model provides a hybrid approach to funding and revenue. It is designed to minimise cost to consumers through use for both regulatory and commercial purposes. The regulatory component (network services) of the battery is funded through the NSW Government Emerging Energy Program, ARENA, and Transgrid's RAB. The commercial component is based on a contract for use with Iberdrola Australia to trade the spare battery capacity that is not required for network services, with capital provided by Lumea security holders. Optimising capacity not required for network services avoids funding 100% through the regulatory processes.

The project is an innovative model of private and public funding working in unison to drive greater benefits at lower costs for NSW electricity consumers. As a result, NSW energy consumers receive:

- A more reliable grid from the pilot of synthetic inertia
- Reduced network service charges through the support of State and Federal funding agencies
- Lower energy costs from increased competition and diversity in the supply of electricity
- Firming to support increased renewable energy generation
- Long-term benefits through the transition to cleaner energy systems

5.2. Funding Model

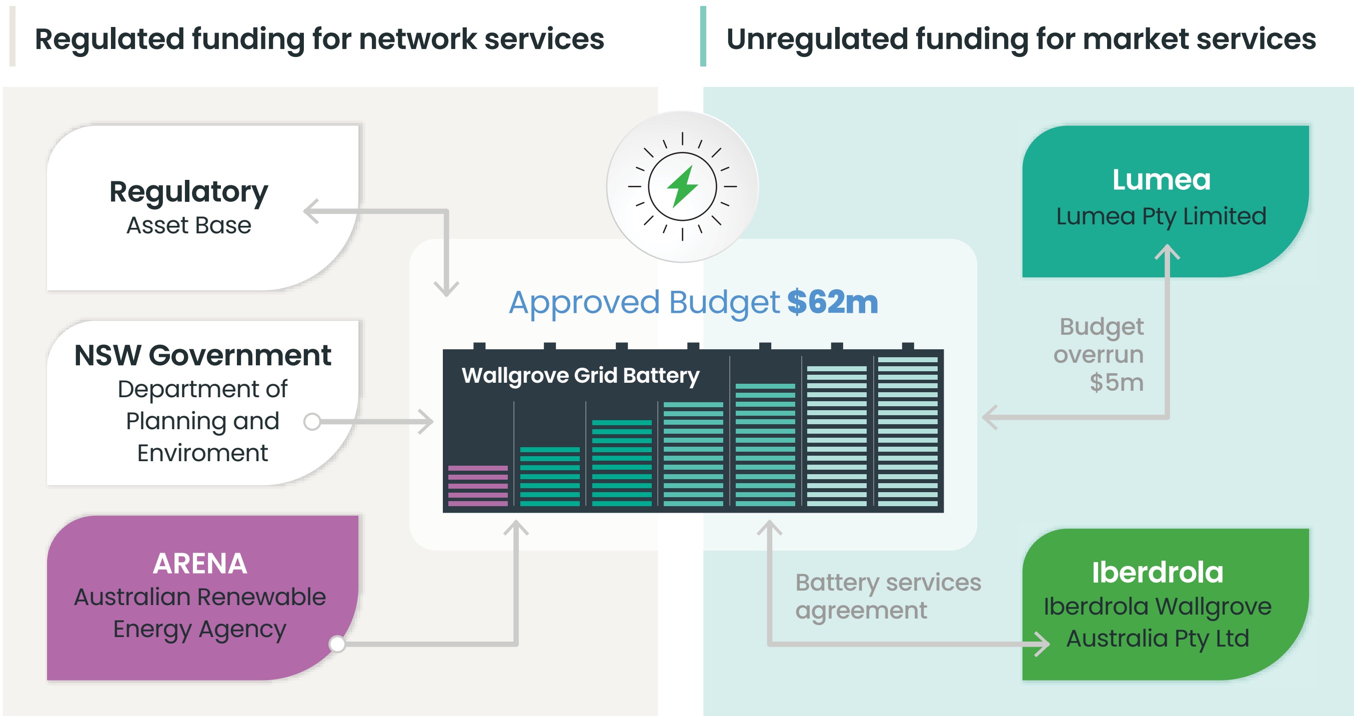


Figure 2 – Funding model

The split between agencies and across regulated and unregulated elements is outlined in the following table.

Table 2 – Funding sources

Source	Network Services Funding	Market Services Funding
Regulated – Transgrid – Regulatory Asset Base (RAB)	$5.9m	
Grant – ARENA*	$10.2m	
Grant – NSW Government	$10.0m	
Unregulated – Lumea –Security holders		$40.6
TOTAL		**$66.7m**

* Repayments are distributed to ARENA (up to an agreed cap) if the battery's net NEM revenue exceeds an agreed threshold.

5.3. Responsibility Model

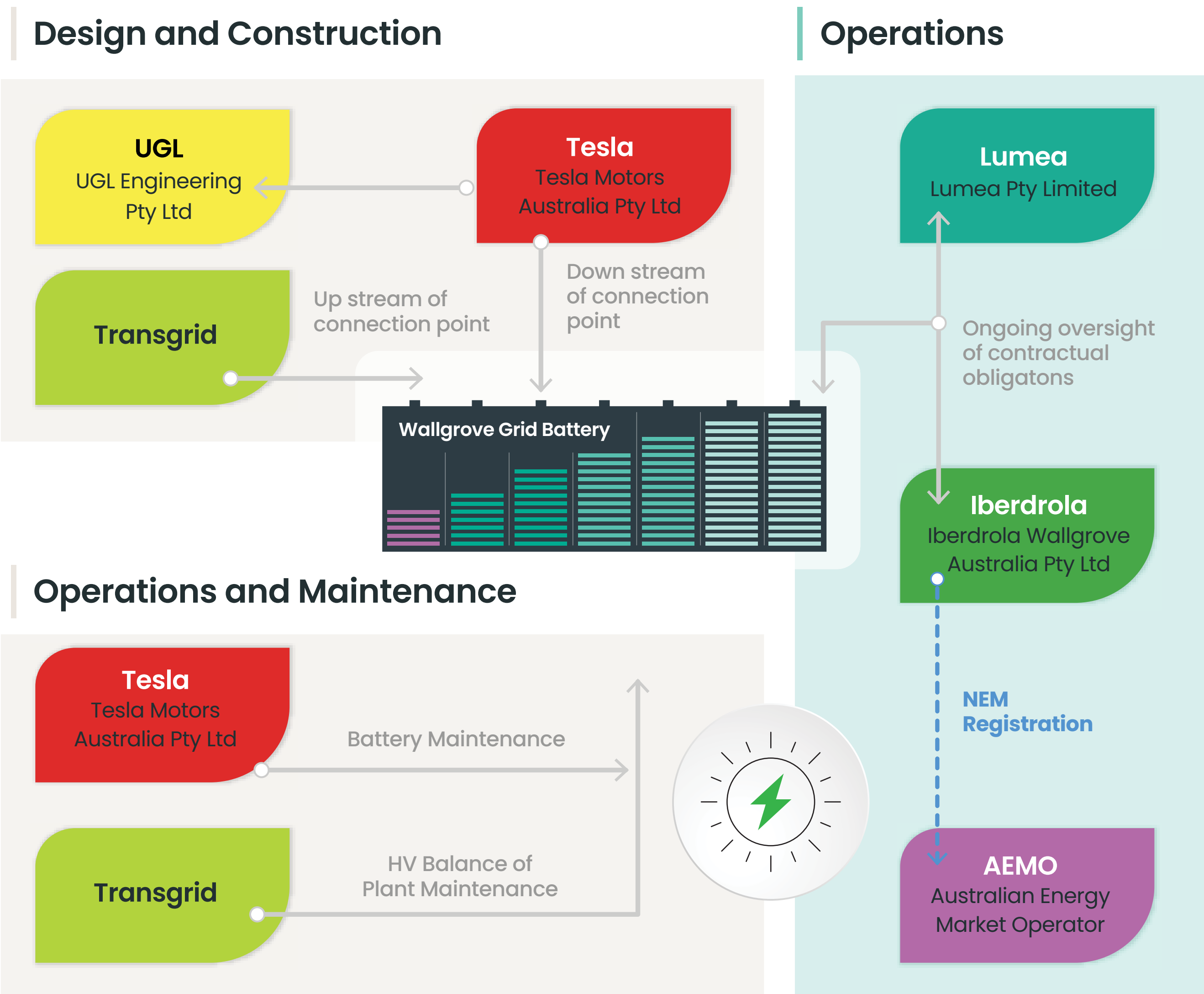


Figure 3 – Responsibility model

The WGB initially aimed to manage project risk through a full wrap of EPC and O&M. However, Lumea ultimately engaged Transgrid to provide O&M on the Balance of Plant (BoP). Tesla was responsible for all EPC works downstream of the connection point, including the high voltage transformer.

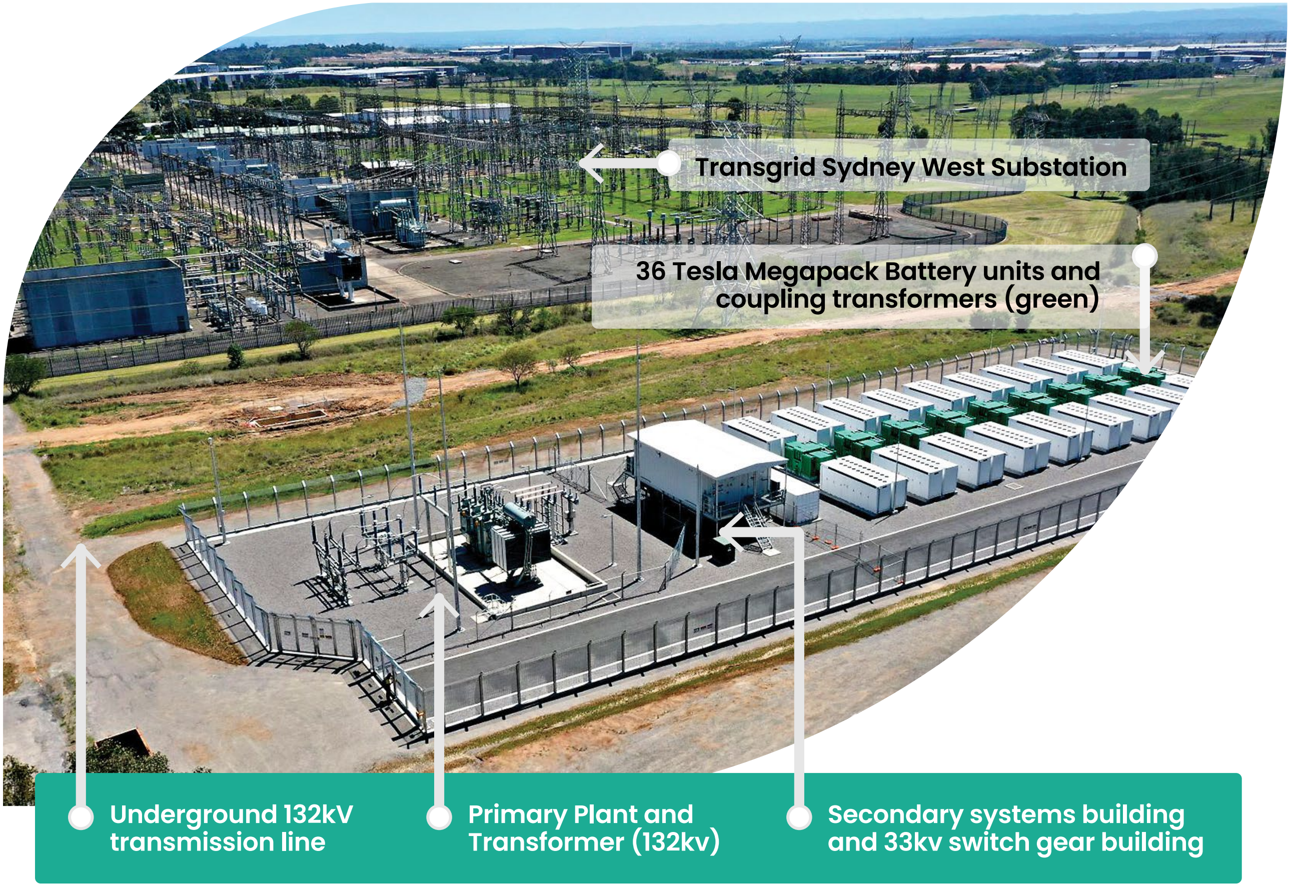


Photo 2 – Wallgrove Grid Battery and Sydney West 330/132kV Substation aerial view

Photo 2 labels key physical assets. Except for the battery packs, all the assets that were delivered by Tesla are now the O&M commercial responsibility of Lumea, as outlined in Table 3, below. A 132kV switchbay was required to connect the transmission line from the WGB within the Transgrid Sydney West Substation. These works occurred in the area at the upper left edge shown in Photo 2 and were performed by Transgrid. They continue to be maintained by Transgrid.

Table 3 – Assignment of responsibilities

Asset	Responsibility in D&C	Commercial liability and management	Service delivery partner
Underground 132kV transmission line	Tesla	Lumea	Transgrid
Primary plant and transformer	Tesla	Lumea	Transgrid
Secondary systems building and 33kV switch gear	Tesla	Lumea	Transgrid
Tesla Megapack battery units	Tesla	Tesla	Tesla
Coupling transformers	Tesla	Lumea	Transgrid
132kV switchbay inside Sydney West Substation	Transgrid	Transgrid	Transgrid

Transgrid undertook all land access and approvals as the asset is located on Transgrid landholdings that form part of the 99-year State Network lease with the NSW Government. A Battery Service Agreement is in place to meet the National Electricity Rules (NER) requirements for network connections.

5.4. Revenue Model

The WGB project receives both regulated and unregulated revenue. The regulated revenue is derived from Transgrid's Transmission Use of System (TUOS) charges and comprises a regulated return on the $5.9m capex allocated to Transgrid's RAB. The AER makes a determination on this return and revenue at five-year intervals in accordance with the NER.

The unregulated portion is associated with Iberdrola Australia's use of the WGB. That component of the project was capitally funded by Lumea's security holders and earns revenue from the fees paid by Iberdrola Australia to Lumea for battery capacity. The ongoing management of contracts is performed by Lumea.

The Battery Services Agreement with Iberdrola Australia Wallgrove Pty Ltd (a subsidiary of Iberdrola Australia Limited) gives Iberdrola Australia the rights and responsibilities to:

- Dispatch control of the WGB in the NEM
- Retain all commercial revenues (and pay all costs) related to the WGB's operation in the NEM (excluding repayments to ARENA if revenue thresholds are exceeded)
- Be the Registered Participant (as an intermediary) for the WGB in the NEM
- Pay Lumea a fee for the right to use the WGB
- Retain energy storage capacity for network services as a priority

The unregulated revenue comprises the fees paid by Iberdrola Australia under their battery services agreement. The term of the battery service agreement is 10 years from the services commencement date of 22 December 2021, at which point a decision will be made regarding revenue streams, based on market conditions at the time.

5.5. Findings from Applying the Model in Practice

5.5.1. Shared funding model

The commercial model demonstrates that regulated and non-regulated revenues can co-exist in the same revenue stack for the benefit of consumers and the network. A network service provider solving the network need alone would have passed higher costs to consumers through increased allocation to the RAB and may not have met the regulatory investment tests in place at the time of investment. By offsetting the costs with a complementary role for private funding and competitive market revenues, the hybrid commercial model creates a stronger network and provides the technology that supports the increasing penetration of renewable generation, while creating more competition that reduces costs to consumers. The additional support of ARENA and the NSW Government directly reduced the burden on bills for NSW energy consumers and provided innovation to support future projects for the transition to renewables.

5.5.2. Lesson Learnt: alignment of financial and physical responsibility for assets

Tesla was the head contractor for project delivery, with design and construction works subcontracted to UGL. One approach to manage risk for projects of this nature is to have a single delivery partner provide a fully wrapped EPC and O&M solution, helping to minimise the risk of gaps in the technical solution. However, for this project the scope of the O&M services and ongoing performance guarantees for the supplier were limited to the battery units, leaving a gap between the assets required for a fully operational BESS and those where performance is guaranteed by the supplier.

Such a model was considered by Lumea to be suboptimal. Lumea assumed commercial responsibility for the operation and maintenance of more of the BoP to ensure the financial and physical responsibility of assets were closely aligned, and risk was allocated to the party best able to manage BoP failure. The service partner for these services is Transgrid. Lumea and Transgrid are part of the Transgrid Group.

The WGB experience on the full wrap resulted in changes to contract structure in relation to risk allocation and is emerging as a market standard, allowing delivery partners to focus on core product. Future BESS projects should seek to ensure that financial and physical responsibilities are aligned.

5.5.3. The challenge of navigating ownership

The commercial transaction needed to ensure the split of investment-protected regulatory and commercial requirements through complex agreements between funding agencies, Iberdrola

Australia, Transgrid and Lumea. Identifying and negotiating partnering strategies was a significant component of the complexity, along with RAB components that are captured under Transgrid's Transmission Operator's Licence. In an outcome quite specific to Transgrid, this introduced limitations in how the WGB project could be financed.

For the WGB, the complexity in commercial model and contracting was unavoidable, however a lesson from the WGB project is to consider the consequences of different ownership approaches at the inception of future projects, in particular the allocation of risk, and financiers' risk appetites. We expect to see both commercial models and financiers' risk appetites evolve in the future as the technology matures.

5.5.4. Changes in costs of components and technologies

At the commencement of the delivery of the WGB project, Transgrid and Tesla worked collaboratively to identify cost-saving opportunities, whilst not compromising the safety, reliability, or security of the asset. The outcome was that minor savings were achieved on equipment, e.g. deviations to Transgrid's transformer specifications were accepted at a commercial advantage without compromise.

As the D&C contract was a fixed price after the contract award, there were no observed additional expenses due to components or technological changes during the project delivery. The only minor change was the result of a slight exchange rate movement between tender and award. While the project encountered some cost overrun as a result of COVID-19 and managing the connection as both a proponent and network (discussed in section 6.1.), this D&C fixed price strategy helped Transgrid manage exposure to cost increases.

5.6. Observed Limitations

5.6.1. Lesson Learnt: complexity of commercial model

The commercial model to fund the WGB project was complex, given the pilot nature and the four different revenue sources (ARENA, NSW Government, regulated revenue and unregulated revenue from Iberdrola Australia). Twelve separate contracts were negotiated with four counterparties with varying contract terms and risk profiles. The project also undertook parallel discussions with the AER and AEMO given the intended network use of the WGB.

All contracts had to be finalised in parallel and drafted to align across separate companies' commercial interests, as well as the priorities and expectations of two separate grant funding bodies. The lesson learnt is that pilot projects involving multiple revenue sources and stakeholders will involve complex contracting and commercial models. Each additional counterparty adds a significant layer of costs and complexity to a project and should be minimised to the extent possible.

There were complexities associated with defining and allocating risks. They were identified and managed during the negotiations and, in some cases, execution. This was largely unavoidable due to the novelty and complexity of the technologies and commercial model deployed for the WGB project. Other proponents of complex/novel projects should expect such "unknown unknowns" and allow additional time and cost in the project development schedule to deal with them or consider strategies to discover them sooner so they can be dealt with earlier and more efficiently.

6.1. Connection Application Approvals

Preparation of the connection application for the battery commenced in May 2020 with research and discussions with AEMO.

As part of the Generator Performance Standards (GPS) and registration phase, AEMO requested that the technical due diligence be performed by two teams within Transgrid, with an information barrier between them. One team represented Transgrid as a Proponent and the other team represented Transgrid in its role as a Transmission Network Service Provider. Transgrid established this structure and engaged a grid consultant to assist with the preparation of the proponent's connection application.

The preparation of the Generator Performance Standards formally commenced in October 2020, at contract commencement. They were approved by AEMO and Transgrid (as the TNSP) on 11 May 2021. The approval of the GPS was a significant milestone within the project, which was completed within the scheduled timeframe.

A connection agreement was completed and notified to AEMO subject to Clause 5.3.7(g) of the NEM Rules, on 17 May 2021. The market participant, Iberdrola Australia, commenced commercial operations of the Wallgrove Grid Battery on 22 December 2021. At that time the battery did not have VMM enabled, as the process of approving registration with VMM would have delayed the commencement of commercial operations and the project delivery milestones were prioritised with the understanding that VMM would be enabled through the course of 2022.

6.2. VMM, GPS and Commissioning Tests

To enable VMM, Lumea proposed to alter the generating system under the 5.3.9 process of the NER. At the time of commencing this process only one other battery (Hornsdale Power Reserve) had gone through a similar alteration process with AEMO. The lack of current incentive structures and the perceived, or actual, complications in connection alterations have prevented more operational batteries from undertaking a similar alteration. As such there were limited market insights on how smooth the connection alteration would be, and whether challenges would arise in relation to either specific clauses in the NER or the AEMO connection process.

During the alteration process, several issues highlighted barriers that exist in connecting grid batteries with grid-forming characteristics. The most significant challenge faced was that under the 5.3.9 process, the performance standards of the existing plant effectively become the minimum standards that the plant must adhere to when alterations are made [clause 5.3.4A(b)(1A) , NER Version 206]. An unintended consequence of the current access standards in Schedule 5.2 of the NER for asynchronous generation is that a project with grid-forming inverter technology is assessed against access standards that appear more suited to asynchronous generating systems that are of a grid-following nature, which can trade-off some of the benefits offered by advanced inverters with grid-forming capability. Grid-forming inverters are more analogous to synchronous machines (which are assessed differently to asynchronous generators under s5.2.5.5 due to these inherent and recognised differences). While the overall performance of the WGB improved, under certain clauses, notably s5.2.5.5, it was not able to meet the existing performance standard agreed for the grid-following configuration.

Lumea established through dialogue with AEMO and ElectraNet that this issue was not faced to the same extent by ElectraNet when they followed a similar process on the Hornsdale battery. Two reasons were established:

- ElectraNet were able to adjust some parameters to enable the battery to meet the minimum access standards for one of the clauses of the GPS, specifically s5.2.5.5. This same approach was not a viable option for the WGB as the performance standards of the existing plant at WGB, and therefore the minimum standards applied to the alteration, were different to those at Hornsdale.

6.3. BESS Storage Reservation for Network Services

6.3.1. Contractual obligations

A portion of the WGB's energy storage capacity is reserved to ensure there is always sufficient energy available to deliver inertia and fast frequency response in case of a significant frequency disturbance. Iberdrola Australia is required to maintain an agreed margin from the minimum and maximum states of charge, to ensure that the BESS is always able to deliver frequency response in either direction in the event of a significant frequency disturbance. These margins are agreed in terms of MWh (not in terms of percentage of capacity) and will always comprise less than 5% of the battery's usable energy storage capacity.

6.3.2. Operational impact for Iberdrola Australia

In line with the contract, Iberdrola Australia is therefore only required to reserve energy storage capacity and is free to bid the WGB's power capacity across the energy and FCAS markets up to the full discharge/charge capacities of 50MW / 47MW respectively.

On a short-term basis (5-minute dispatch intervals), Iberdrola Australia takes a view on the potential for WGB's dispatch to encroach upon these contractual state of charge thresholds, limiting dispatch in a market (typically Regulation FCAS or Energy) where there is a possibility of excessively charging or discharging. As the state of charge is actively managed throughout the day, it is very rare for the BESS to be restricted in terms of participating in the Energy and FCAS markets to below its full capability, especially in the provision of Contingency FCAS.

The constraints on reserving energy storage capacity do need to be considered over the medium-term operations of the battery where an extended charge or discharge will bring the battery to the limits of its energy storage capacity (either ~0% or ~100% energy storage capacity).
Iberdrola Australia's bidding strategy is consistent with naturally reserving energy storage headroom for either dispatching or charging the battery for unforeseen market volatility. Analysis of operational data over the past two years demonstrates that Iberdrola Australia prefers to maintain at least 15 percent of energy storage capacity reserved to capitalise on unforeseen market events.

Given the alignment of reserving energy storage capacity for network services and Iberdrola Australia's bidding strategy, there have been limited operational impacts on market services from complying with the network service requirements.

6.4. Inertia Provision and Market Revenues

As the commercial operation of the battery was not encumbered by requirements to reserve power capacity for the network service, analysis of the operational data provides insight into the availability of the WGB to provide the necessary responses.

Figure 4 shows a summary of the WGB's dispatch behaviour in the NEM from the commencement of operations in late 2021, to the introduction of the very fast frequency response market in October 2023. The battery is idle and therefore available to provide inertia and FFR in both directions at its nameplate capacity approximately 22% of the time. The steepness of the chart at either end shows that the battery charges or discharges near or at its full capacity in limited situations. This means that for the vast majority of the time, most of the nameplate capacity is available in both directions to provide either a raise or lower FFR and/or inertial response.

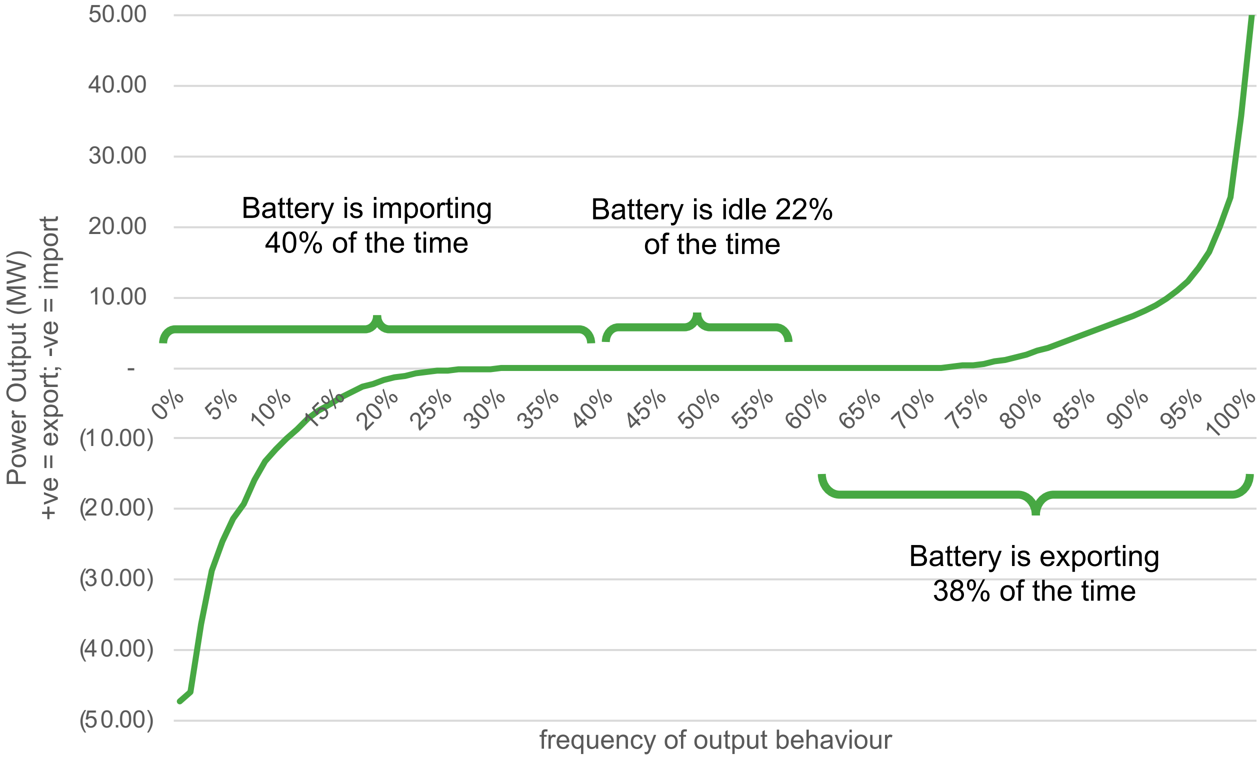


Figure 4 – Wallgrove Grid Battery power output (MW) 23 December 2021 to 8 October 2023

6.4.1. Availability for inertia and FFR

As noted previously, when the battery is idle, 100% of its nameplate capacity is available for raise and lower services. When it is actively charging or discharging, there is a corresponding increase in available capacity for the opposing service, i.e. when charging, the WGB has more than its nameplate capacity available for raise services as the frequency response reverses the load and then discharges. The scale of the available capacity is therefore between 0 and 200% of the nameplate, with a slight accommodation for the asymmetric charging and discharging registrations.

6.4.1.1. Availability to provide raise services

Wallgrove Grid Battery: 23 December 2021 to 8 October 2023

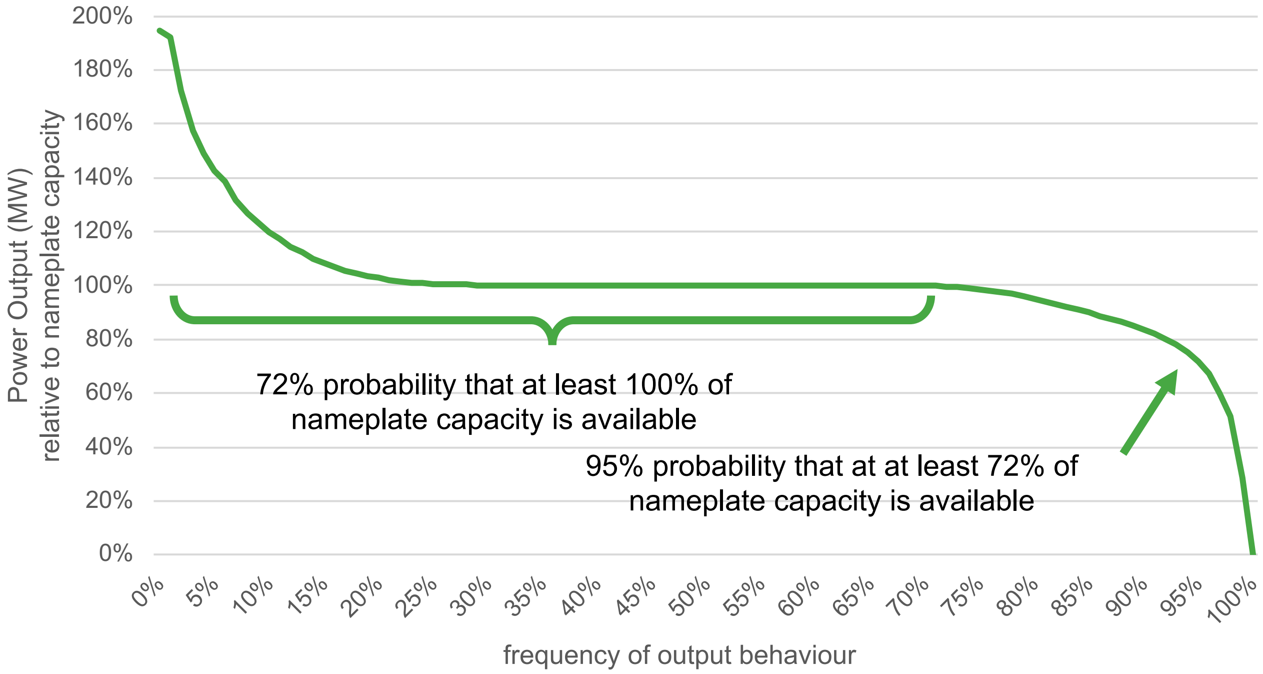


Figure 5 – Percentage of nameplate capacity available for inertia and FFR (raise)

Key findings:

- At least the WGB's full nameplate capacity is available to provide raise services approximately 72% of the time.
- For 95% of the time, at least 72% of the WGB's nameplate capacity is available to provide raise services.
- For a quarter of the time, greater than 100% of the nameplate capacity is available to provide raise inertia services.

6.4.1.2 Availability to provide lower services

Wallgrove Grid Battery: 23 December 2021 to 8 October 2023

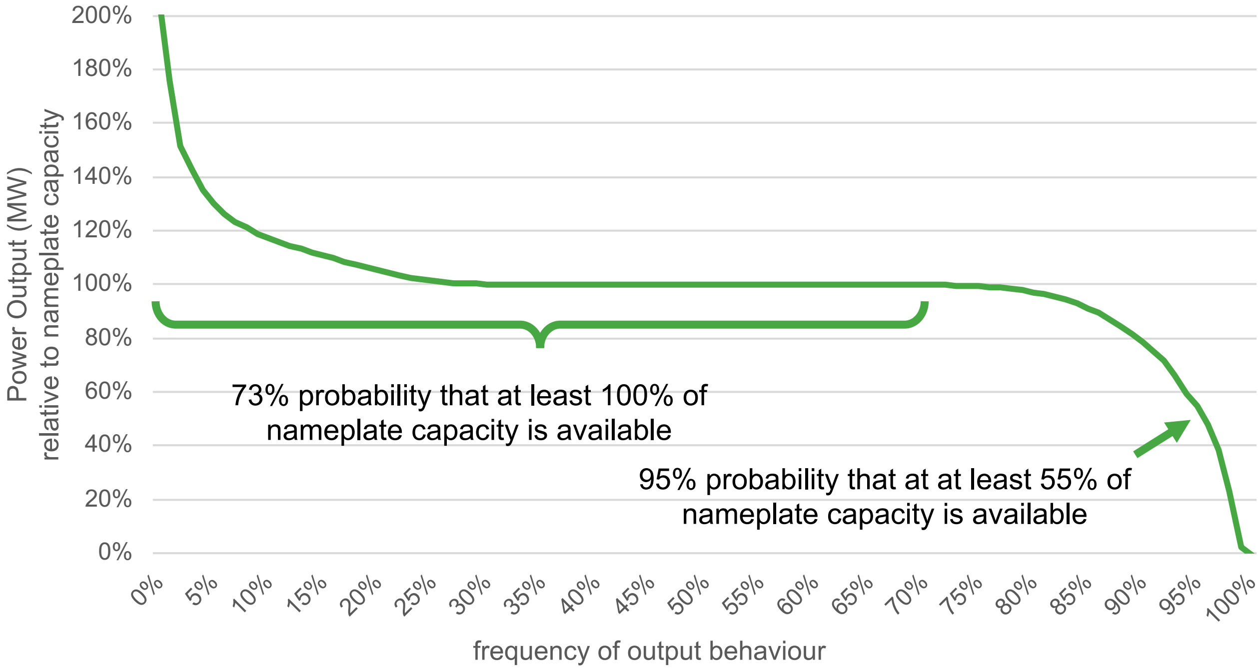


Figure 6 – Percentage of nameplate capacity available for inertia and FFR (lower)

Key findings:

- The WGB's full nameplate capacity is available to provide lower services approximately 73% of the time.
- For 95% of the time, at least 55% of the WGB's nameplate capacity is available to provide lower services.
- For a quarter of the time, greater than 100% of the nameplate capacity is available to provide lower inertia services.

6.4.1.3. Conclusions on complementarity

This analysis shows that without imposing any restrictions on Iberdrola Australia's use of the WGB, the battery can provide FFR and inertia to at least nameplate capacity around three-quarters of the time, i.e. to a large extent the commercial operations do not inhibit the provision of the network service.

Under the current NER, a battery that has been contracted to provide inertia only needs to guarantee the provision of inertia when "enabled" by AEMO, and this would only occur when there is a credible contingency event that could result in a region of the NEM being islanded. While it demonstrates that in times of network need anything less than 100% available is not an option, discrete procurement of inertia, particularly considering evidence of the complementarity between market and network services such as the above, speaks to an opportunity for further market development.

FFR became a market service in October 2023, giving AEMO the ability to co-optimise the provision of FFR along with energy and FCAS via the NEM dispatch engine. In simple terms, this means Iberdrola Australia (via the bidding process) and AEMO (via the dispatch process) can choose the combination of energy, FCAS, and FFR services that is most complementary and optimal for the network and market conditions at that time.

A future inertia market could operate in the same way when the volume of batteries with grid-forming inverter capability continues to grow along with the appreciation of how much inertia they can provide.

6.5. Market Revenue

The market revenues for WGB in its first two years of operation are outlined in Figure 7 below.

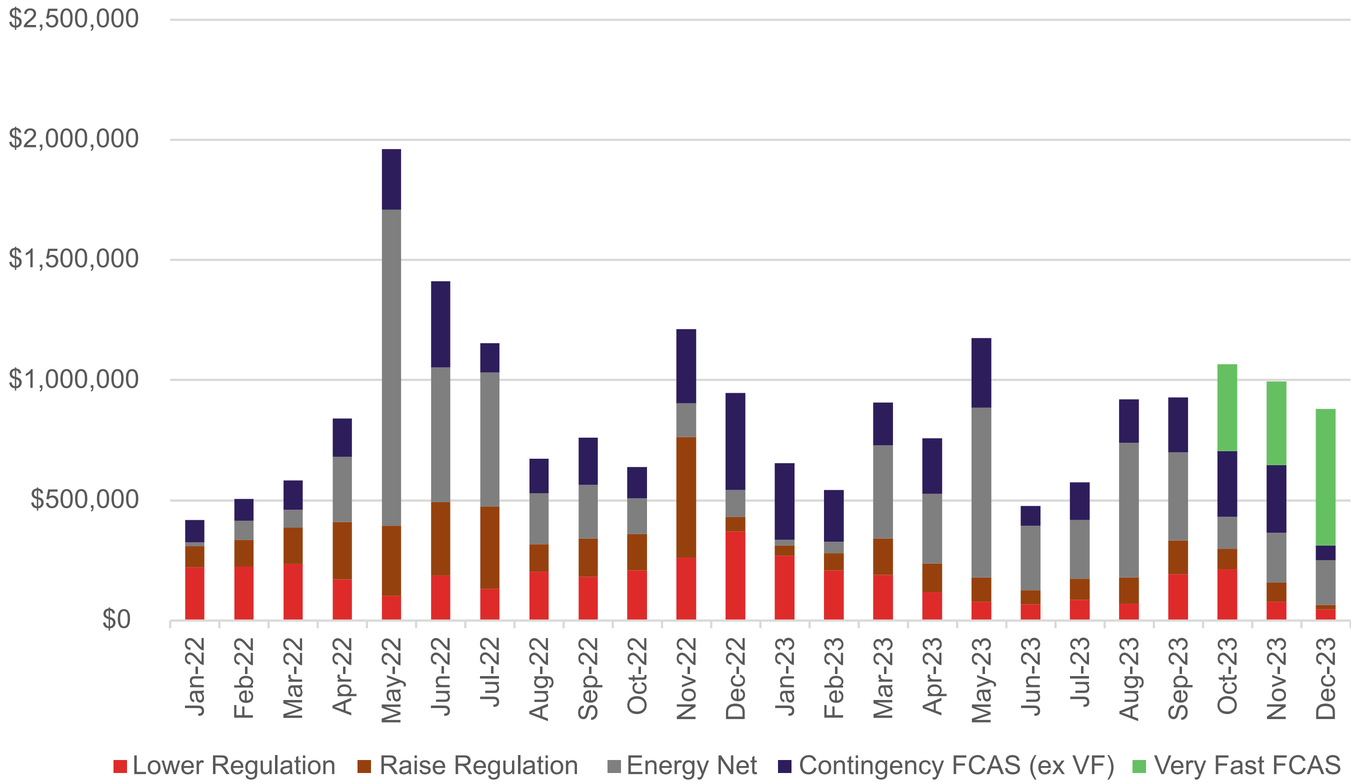


Figure 7 – Monthly revenue by market

Key points of interest in the performance over the first two years of operation are:

- Capturing revenue in periods of increased market volatility is crucial to the overall financial performance of BESS projects, with large amounts of revenue available across short timeframes.
  - This in turn highlights the importance of ensuring that a battery is flexible enough to operate with a higher capacity factor during these volatile periods (e.g. no daily cycle limits) and has a high system availability (given that these events may occur at unpredictable times based on external shocks to the market).
- Generally, higher revenue opportunities have been seen to occur during the shoulder periods in the electricity market (outside of Summer and Winter periods) where thermal generators are traditionally taken offline for maintenance works.
  - Similarly, there have been limited revenue opportunities seen in the first two years of operations for WGB during the Summer quarter (January to March) with comparably mild summer conditions experienced in these two years.
- Flexibility in the BESS to participate in new markets from their implementation is key to capturing any initial market opportunities, as seen with the revenues earned in the first few months of the very fast contingency FCAS markets from October 2023.

6.6. Market Revenue by Application

Figure 8 – Proportions of revenue contribution in each season over the first two years of the project

Analysis of the seasonal breakdown of revenues in Figure 8 demonstrates that proportionally the WGB is more dependent on energy arbitrage for its revenue in the cooler periods of autumn and winter. In each season in the second year of operation, a trend away from regulation FCAS and toward contingency FCAS is evident, though the sample size is quite small. . This decrease in regulation FCAS market revenues, as shown in Table 4, ties back to increased energy price spreads around the NEM market suspension in June 2022. Aggregate revenues earned across all markets were seen to remain relatively stable throughout the first two years of operation, though volatility within each market and the influence of emerging markets makes it difficult to predict the future prospects.

Table 4 – Revenue contributions over the first two years of the project.

Service ($m)	January – June 2022	July – December 2022	January – June 2023	July – December 2023
Contingency FCAS	1.1	1.3	1.3	1.2
Very Fast FCAS				13
Regulation FCAS	2.3	2.7	1.5	1.2
Energy	2.3	1.4	1.7	1.7
Total	**5.7**	**5.4**	**4.5**	**5.4**

6.7. Marginal Loss Factors

Given that the WGB is adjacent to the regional reference node of the NSW region, the long-term stability of the generator and load MLFs were expected to have a negligible impact on the revenues generated by the battery in the energy market. This is reflected in the historic MLFs determined for financial years 2022, 2023 and 2024 shown in Table 5.

Table 5 – MLF values for the Wallgrove Grid Battery

Financial Year	WALGRVG1 (generator)	WALGRVL1 (load)
2021-2022	1.0011	1.0010
2022-2023	1.0010	1.0009
2023-2024	1.0010	1.0009

6.8. Data Sources

The revenue figures shown 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/

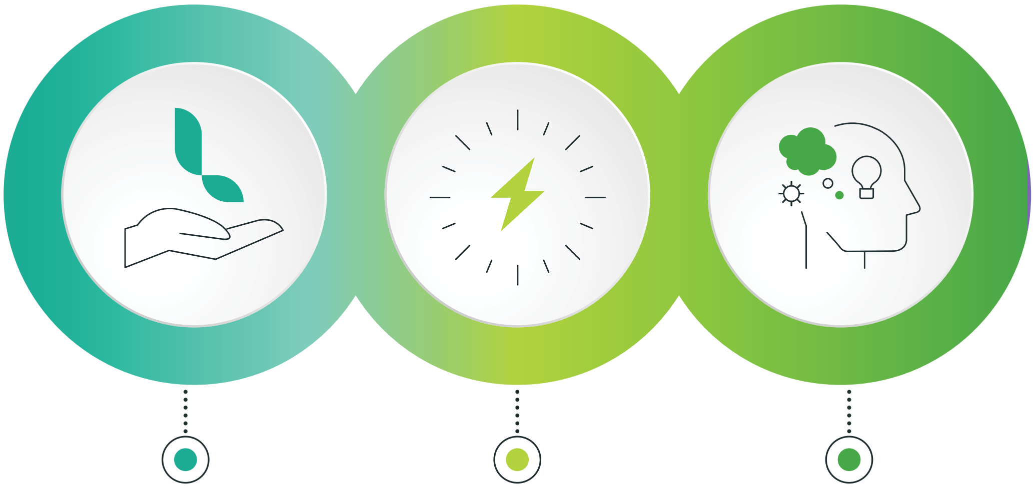
6.9. Safety and Environmental Performance

There have been no safety or environmental incidents in the first 24 months of operations.

Table 6 – Work hours on site

Operational period	Approximate work hours onsite
1 January 2022 – 30 June 2022	1,040
1 July 2022 – 31 December 2022	1,214
1 January 2023 – 30 June 2023	1,414
1 July 2023 – 31 December 2023	543

7.1. Benefits



Enhanced reliability

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

More affordable power

Finding the 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.

7.2. Contribution toward lowering investment barriers

The grid-scale battery development landscape has shifted dramatically since work began on the WGB in 2020. The support provided by the NSW Government and ARENA in supporting the Project was a crucial catalyst for the rapid growth and maturation that has taken place.

Investment barriers were fundamentally high because of the perceived technology risk and the lack of understanding of how batteries would perform in the energy market. Equity investors priced significant risk into their return expectations, and all projects were heavily dependent on grant incentives and concessionary financing. Now, an increasing number of investors, both international and domestic, are competing for access to the asset class, driving down return expectations and investment barriers as a result.

Through demonstration projects such as the WGB, investors are now more comfortable with the risks associated with batteries, particularly lithium-ion based chemistries. As a result, the investment focus has shifted from uncertainty on the battery product, to optimisation in how it is configured, and how extra value can be created through more aggressive off take positions and EPC structures. Battery developments are increasingly commercial, particularly over shorter durations, where grant support is now no longer required to meet investment hurdles.

Lenders also now understand the market for batteries in a much more nuanced way, with banks now willing to invest on a merchant basis, where previously only contracted cashflows were bankable. While the WGB has only been operational for just over two years, the 'plain vanilla' toll off-take structure that was common at that time, is now comparatively antiquated, with hybrid models involving virtual tolls and merchant exposure increasingly common. These financial products are disrupting access to the market, and opening participation beyond the traditional top-tier energy retailers. This makes retail energy more competitive, ultimately driving down the cost of energy for the everyday consumer.

7.3. Wallgrove Grid Battery as a foundation for the future

The contemporary battery development landscape demonstrates that we are already living in a future built on the foundations laid by the WGB.

The WGB was an early trial of advanced inverters of a grid-forming nature. This technology is now increasingly commonplace, with projects more likely to include grid-forming technology than not, to manage their obligations and potentially generate revenue from network services. This development has significant implications for the reliability of the grid as it becomes increasingly based on intermittent renewables, as now batteries, rather than synchronous machines, are proving their worth in providing the necessary network services to maintain a strong grid through the clean energy transition.

The Transgrid Group has significantly progressed its understanding of grid-forming inverter technology through the deep consideration and analysis of the WGB in responding to grid disturbance. The knowledge-sharing program established in collaboration with the NSW Government and ARENA has been critical in structuring this work, laying a positive foundation for future consideration of how different technologies will support the grid in different places.

As discussed, there has been an influx of investors competing for access to the battery asset class. The availability of competitive capital has stimulated growth on the supply side, with more than 20 participants vying to sell original equipment to new projects, challenging the early few entrants. The momentum behind battery development means the current operating capacity of batteries in the NEM is dwarfed by the volume currently in construction. This is a powerful legacy built by the WGB through the support of the NSW Government and ARENA.

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