Gannawarra Energy Storage System

Operational Report #1 and #2

Edify Energy and EnergyAustralia
hello@edifyenergy.com

Table of Contents

List of Figures

List of Tables

Disclaimer

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

Glossary of Terms

Acronym	Meaning
AC	Alternating Current
AEMO	Australian Energy Market Operator
API	Application Programming Interface
ARENA	Australian Renewable Energy Agency
BSSA	Battery Storage Services Agreement
DELWP	The Victorian Government's Department of Environment, Land, Water and Planning
DLF	Distribution Loss Factor
DUOS	Distribution Use of System
Edify	Edify Energy Pty Ltd and its related entities
EPC	Engineering, Procurement and Construction
FCAS	Frequency Control Ancillary Services
GESS	Gannawarra Energy Storage System
GSF	Gannawarra Solar Farm
LLV	Large Low Voltage
MLF	Marginal Loss Factor
NEM	National Electricity Market
NMI	National Metering Identifier
Project	GESS
RCR	RCR Tomlinson Limited
RRN	Regional Reference Node
SCADA	Supervisory Control and Data Acquisition
SOC	State-of-Charge
ST	Subtransmission
WIRCON	Wircon Energie 9 GmbH and its related entities

Executive Summary

The 25MW / 50MWh Gannawarra Energy Storage System has already provided a range of insights into what – from a development, regulatory and deployment perspective – is required to retrofit a new battery system to an existing solar farm; in this case the 50MW$_{AC}$ Gannawarra Solar Farm. This operational report extends these learnings to provide insights into how a battery and solar system, sharing the same connection infrastructure, behaves in an operational setting. It does so over the two 6-month periods of March to August 2019 and September 2019 to February 2020.

Key insights to be gained from these first two 6-month periods of operation include:

- The shared network infrastructure does not preclude the battery system from performing effectively across the readily accessible markets of energy and FCAS;
- Performance in the energy market has been in line with expectations and was assisted by highly volatile days, where the supply / demand balance was tight;
- Regulation FCAS performance has exceed expectations and has been the stand-out revenue generating performer for the asset since becoming registered in June 2019;
- The facility is not yet providing contingency FCAS services, but this is simply because it has not yet been registered to do so and is not related to any physical capability limitations or the nature of its connection;
- GESS has been managed using human insight and trading, rather than taking up the option of automatic bidding;
- The approach to trading has been to manage the SOC of the battery around the timing of peak demand periods, which is adjusted by season, and to determine the number of cycles / energy dispatched based on the typical spread in prices in the period;
- Concurrent regulation FCAS participation has been used effectively to amplify the revenue potential of individual cycles and to improve the effective cost of charging;
- The two major constraints on operations that GESS experiences, that may be in contrast to other battery systems in the NEM is 1) the application of DUOS charges by Powercor (being distribution network connected); and 2) the management of the 50MW substation headroom constraint around the output of the solar farm;
- Despite the significant financial burden that the application of DUOS charges means for charging outside of solar hours, GESS has to this point in time still found it optimal to perform a lower capacity (10MW) charge overnight as this correlates with the lowest price periods and allows the battery to have an available SOC to capture some morning price peaks;
- The primary challenge in managing the substation headroom constraint relates to inaccuracies in the forecast of GSF, where a forecast that is higher than actual can result in underutilised headroom that could have been used by GESS, particularly during tight network events;
- It is expected that a transition to the more accurate self-forecasting (and away from a reliance on AEMO's forecast) will mitigate these challenges, as will the movement to more coordinated IT system interfaces; and
- GESS performed strongly from a technical perspective over the reporting period, with high rates of availability and no safety or environmental incidents to report.

Project partners

GESS would not have been possible without the support of DELWP as part of its Energy Storage Initiative, ARENA as part of its Advancing Renewables Program or WIRCON as 50-50 joint venture co-investors. GESS's other project partners Tesla and EnergyAustralia also worked tirelessly to turn the project from concept to reality.

INTRODUCTION

Edify™

1 Introduction

This Operational Report #1 and #2 covers the time from completion to the end of the first 2 x six month periods (March to August 2019 and September 2019 to February 2020) of operation of GESS. This report represents two of the Knowledge Sharing deliverables under the Funding Agreement with DELWP and ARENA, and also forms a key part of ARENA's Advancing Renewables Programme objectives.

The report focuses on operational learnings, including the following:

- Operational regimes (e.g. arbitrage and firming);
- Ancillary Services provided;
- Technical performance;
- Financial performance; and
- Safety and environmental performance.

The report is public with an intended audience that includes:

- Developers;
- Renewable energy industry;
- General public;
- Vendors;
- General electricity sector; and
- Governments.

1.1 Knowledge sharing activities to date

To date, a number of knowledge sharing activities for GESS have taken place as listed in Table 1.

Table 1 Knowledge sharing activities to date

Activity	Details
Industry presentations	• RenewEconomy / Informa Conference; June 2018 • All Energy Conference; October 2018 • Baker McKenzie panel seminar; October 2018 • AEMO Advanced Systems Integration Group (ASIG) meeting; October 2018 • ARENA Insights Forum; November 2018 • Australian Solar + Energy Congress and Expo; December 2018 • Clean Energy Summit; July 2019
Reports and other published materials	• ARENA's GESS video, November 2018[1] • AEMO Emerging Generation and Energy Storage (EGES) stakeholder paper response; December 2018[2] • Energy Magazine Article; February 2019[3]

[1] https://youtu.be/tEUiqYu28OA
[2] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Initiatives/Emerging-Generation/Submissions/Edify-Energy_20181204.pdf
[3] https://www.energymagazine.com.au/exploring-the-retrofit-model-and-offtake-agreements-for-battery-integration/

	• ARENA Insights Spotlight: Gannawarra Energy Storage System (GESS) An interview with Edify Energy, April 2019[4] • DELWP's GESS media release and video, July 2019[5] • Project Summary Report, September 2019
Site visits	• Construction visit; August 2018 • Completion visit; June 2019[6]

1.2 About Edify Energy

Edify is a leading 100% Australian owned renewable energy company, with significant experience in developing, project financing and delivering renewable and storage projects across Australia. Edify has under construction, or brought into operation, six large-scale solar farms (640MW_{AC} / 770MW_{DC}) and a 25MW / 50MWh lithium-ion battery.

The Edify business model supports the full lifecycle of energy project development and operation, including greenfield development, project structuring and financing, construction management and a full asset management offering, including trading, reporting and managing operations and maintenance personnel. Edify's philosophy is to ensure that its interests are as closely aligned with investors and project stakeholders as possible. For this reason, in addition to providing long-term asset management services, Edify seeks to maintain an equity interest in its projects, resulting in best-in-class assets.

The Edify management team has in excess of 130 years' experience in the power and renewables sector internationally, raised and deployed around $3 billion in capital, brought over 40 solar and wind projects into commercial operation and overseen the construction and operation of a collective operational portfolio of more than 1.7GW. Edify operates as a team across Australia in capital cities and in towns close to the project sites, maintaining a strong connection with the communities in which the solar power and storage plants operate.

Table 2 outlines the projects that Edify has developed, structured, financed and managed the construction of to date. With the exception of the under-construction Darlington Point Solar Farm, all projects are operational and under Edify's asset management function.

As is noted in Section 1.4 below, GSF and GESS required the creation and registration of a network in order to enable the connection arrangement for these two assets. Edify is one of very few energy companies that has overcome many of the challenges presented in the energy sector's transition in that, in addition to the GESS / GSF network, Edify has developed, structured, financed and has under construction or operation renewable assets, a battery, harmonic filters and a synchronous condenser.

[4] https://arena.gov.au/assets/2019/04/gannawarra-energy-storage-system.pdf
[5] https://www.energy.vic.gov.au/media-releases/australias-largest-integrated-battery-and-solar-system
[6] https://reneweconomy.com.au/edify-energy-celebrates-completion-of-gannawarra-big-battery-73122/, https://www.abc.net.au/news/2019-06-14/australias-largest-solar-and-battery-farm-opens-in-kerang/11209666

Table 2 Edify Energy's Australian development and transaction experience

Project	Capacity	Location	Status	Comment
Whitsunday Solar Farm	58MW_{AC} 69MW_{DC}	Collinsville, QLD	• Operational • Commissioned 2018	• Received ARENA funding • Secured largest Solar 150 Support with QLD Government • Debt funding with CBA, CEFC and NORD LB
Hamilton Solar Farm	58MW_{AC} 69MW_{DC}	Collinsville, QLD	• Operational • Commissioned 2018	• Short-term PPA with ERM Power for full output • Debt funding with CBA, CEFC and NORD LB
Daydream Solar Farm	150MW_{AC} 180MW_{DC}	Collinsville, QLD	• Operational • Commissioned 2018	• PPA with Origin Energy for full output • Equity funding with BlackRock • Debt funding with CBA, CEFC and Natixis
Hayman Solar Farm	50MW_{AC} 60MW_{DC}	Collinsville, QLD	• Operational • Commissioned 2018	• Merchant project • Equity funding with BlackRock • Debt funding with CBA, CEFC and Natixis
Darlington Point Solar Farm	275MW_{AC} 330MW_{DC}	Darlington Point, NSW	• Commissioning	• PPA with Delta Electricity for portion of output • Equity funding with Octopus Investments • Debt funding with CBA and Westpac
Gannawarra Solar Farm	50MW_{AC} 60MW_{DC}	Kerang, NSW	• Operational • Commissioned 2018	• PPA with EnergyAustralia for full output • First large-scale solar farm in Victoria • Debt funding with CBA, CEFC and NORD LB
Gannawarra Energy Storage System	25MW / 50MWh lithium-ion battery	Kerang, NSW	• Operational • Commissioned 2018	• Grant funding provided by ARENA and VIC Government • Long-term services agreement with EnergyAustralia • One of the largest co-located solar farm and battery facilities in the world

1.3 About EnergyAustralia

EnergyAustralia provides gas and electricity to more than 2.5 million residential and business customer accounts in Victoria, New South Wales, the Australian Capital Territory, South Australia and Queensland. EnergyAustralia is dedicated to building an energy system that lowers emissions and delivers secure, reliable and affordable energy to all households and businesses. To support this, EnergyAustralia owns, contracts and operates an energy generation portfolio that includes coal, gas, battery storage, demand

response, solar and wind assets. Combined, these assets comprise 4,500MW of generation capacity. EnergyAustralia, which has its headquarters in Melbourne, is a wholly-owned subsidiary of CLP Group, one of the largest publicly-owned integrated power businesses in the Asia Pacific. Read more about us here: www.energyaustralia.com.au

1.4 Project overview

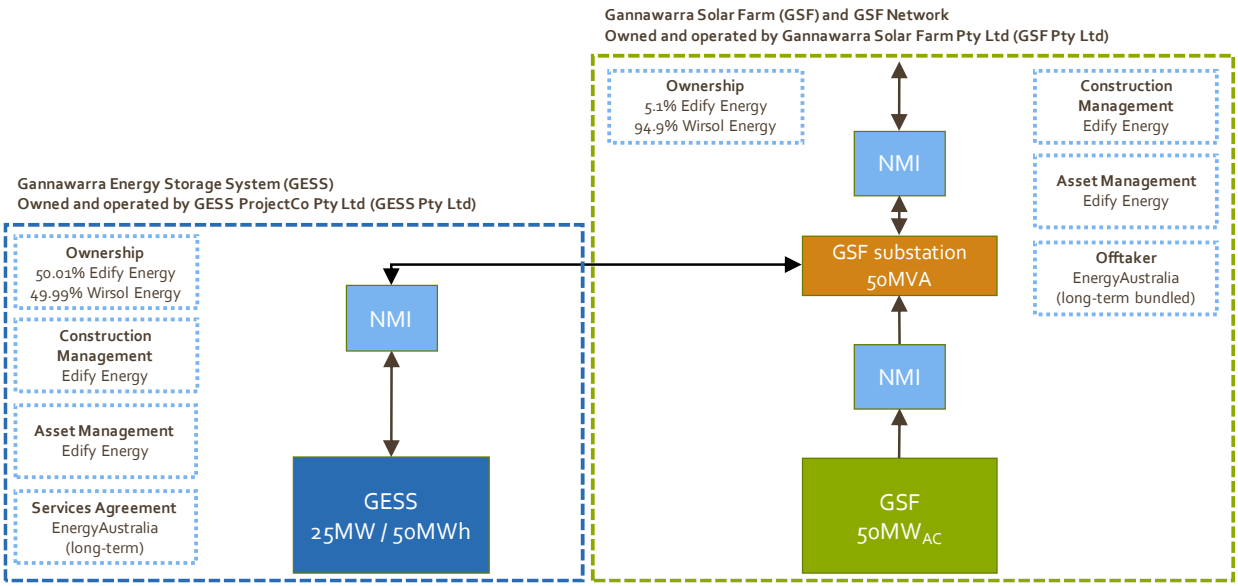
GESS is a 25MW / 50MWh battery that is integrated with Victoria's first large-scale solar farm – GSF (being a 50MW$_{AC}$ solar farm). GESS was developed and structured by Edify and financed by ARENA and DELWP as providers of $25 million in grant funding with Edify in a consortium with WIRCON as 50-50 joint venture co-investors. Tesla was the battery provider, RCR the EPC contractor and EnergyAustralia is the long-term operator of GESS under a novel BSSA.

Now complete and commissioned, GESS is:

- The first integrated utility scale renewable energy and battery system in Victoria and among the first in Australia;
- The first retrofit of a battery to an existing or under-construction solar farm in Australia;
- Among the largest integrated renewable energy and battery systems in the world; and
- A pioneering project for all consortium members and the broader electricity sector given its importance in identifying necessary reforms to bring batteries and other storage technologies to market.

Figure 1 indicates the commercial relationships for GESS and how they interact with GSF. In addition to developing and being a majority owner of GESS, Edify also acts as asset manager and oversaw the construction of GESS, in a similar way to its role in GSF. Importantly, EnergyAustralia holds a long-term offtake position with GSF, that complements its operational role for GESS under the BSSA.

Figure 1 Commercial arrangements for GESS and its interaction with GSF



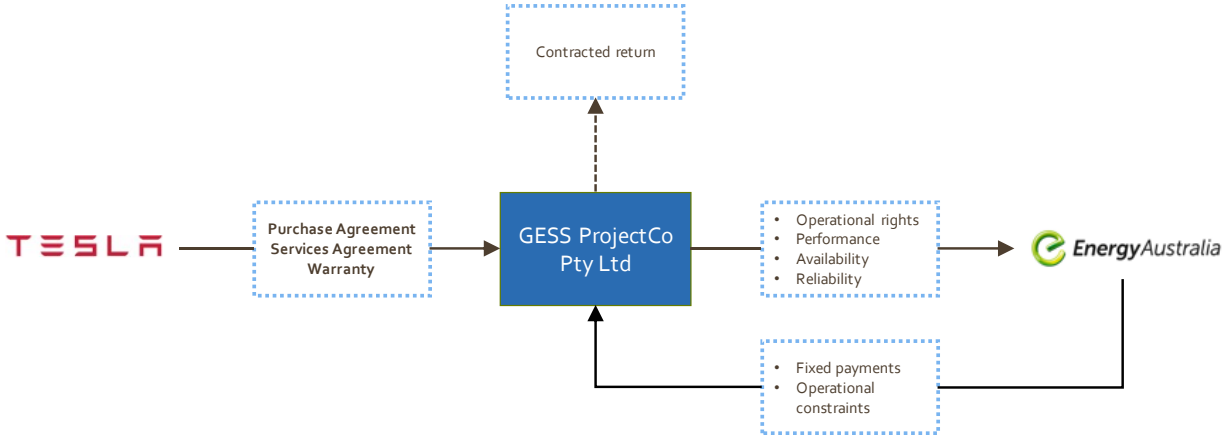
1.4.1 EnergyAustralia as operators

The revenues of GESS are wholly captured in the novel long-term BSSA between GESS and EnergyAustralia. The BSSA entitles EnergyAustralia to full operational rights over GESS, as they relate to charge and discharge decisions in both energy and FCAS markets. Accordingly, EnergyAustralia is the

beneficiary of all market-linked revenues from GESS, which it receives in exchange for making fixed payments to GESS.

The BSSA also provides EnergyAustralia with battery performance, availability and reliability commitments, subject to operational constraints, mainly relating to cycling frequency and depths and dispatch capacity limits relating to sharing a connection with the co-located solar farm. The battery purchase agreement provides GESS with performance, availability and reliability commitments from Tesla. Figure 2 outlines these arrangements.

Figure 2 Structure of the novel long-term services agreement with EnergyAustralia



OPERATIONAL REGIMES

Edify™

2 Operational regimes

2.1 Services provided

As outlined in Section 1.4.1, EnergyAustralia is the registered market intermediary for GESS and is therefore responsible for the bidding of the battery system with AEMO. GESS has been registered as both a Scheduled Market Generator and a Scheduled Market Load in the NEM, and since July 2019 has been registered in the regulation FCAS markets. In its first twelve months of operations, the EnergyAustralia trading teams have not included GESS's volume in EnergyAustralia's firm trading position for the management of cap contracts and other physical positions. Rather the primary use case for GESS has been for energy arbitrage and providing regulation FCAS services.

From an operations perspective, EnergyAustralia has chosen to optimise GESS using human insight rather than adopting an automated trading tool. This decision was driven by two primary considerations on EnergyAustralia's part:

1. A desire to use the battery as a learning tool to understand how flexibly it performs and responds and to apply those learnings within a portfolio of other assets and to tune any future automation; and

2. Where market / price forecasts are highly accurate then auto bidding can be an optimal approach, but many factors can change moving closer to dispatch intervals and specific market outcomes. For instance:

   – Demand / supply forecasts can deviate greatly, particularly with renewables playing a large part in the variability of supply;
   – Forced outages / de-ratings and lack of participant bidding until close to dispatch can cause auto bidding to produce sub-optimal results especially around managing SOC where the expected high price period of the day may evolve as the day progresses; and
   – FCAS price forecasts can be inaccurate, so relying on a high level of FCAS related cycling without an accurate forecast would be difficult.

Batteries can engage in all markets independently whereas traditional generation sources are required to be online supplying energy before being available to supply ancillary services. With contractual limitations around the number of available cycles and SOC, arbitrage value within the energy market is less guaranteed, so FCAS markets have been explored for value. It was found that a cycle can be extended 4-5 times by bidding into FCAS markets compared to energy alone. This strategy allows for payments to be made to GESS for being on standby, and when reacting to FCAS enablements also being paid within the energy market. Similarly, charging GESS ordinarily results in a cost being incurred, which is dependent on the market price plus accounting for losses and network costs. However, by utilising raise FCAS services while charging, GESS can at times be paid to stop charging, which offsets the normal cost of the charge.

From a SOC management perspective, the high-level strategy adopted over this reporting period for GESS was to keep the battery SOC at a high percentage prior to the peak demand periods. This shape changes depending on the seasons. For instance, during Winter months the battery is charged overnight and the afternoon maintaining a high SOC to provide energy dispatch when the market requires it. The spread between the low / high price is used to dictate the amount of energy / cycles that are dispatched per day.

There will be value registering GESS for contingency FCAS to allow for use of more of the cycles and increase revenue; however, it is uncertain how the value of these ancillary services will change over time with the introduction of more batteries and mandated primary frequency control.

At present GESS does not provide additional non-market services, however in accordance with the agreed performance standards and the capability of the plant, we continue to scan for opportunities that a fast responding asset of this type can provide.

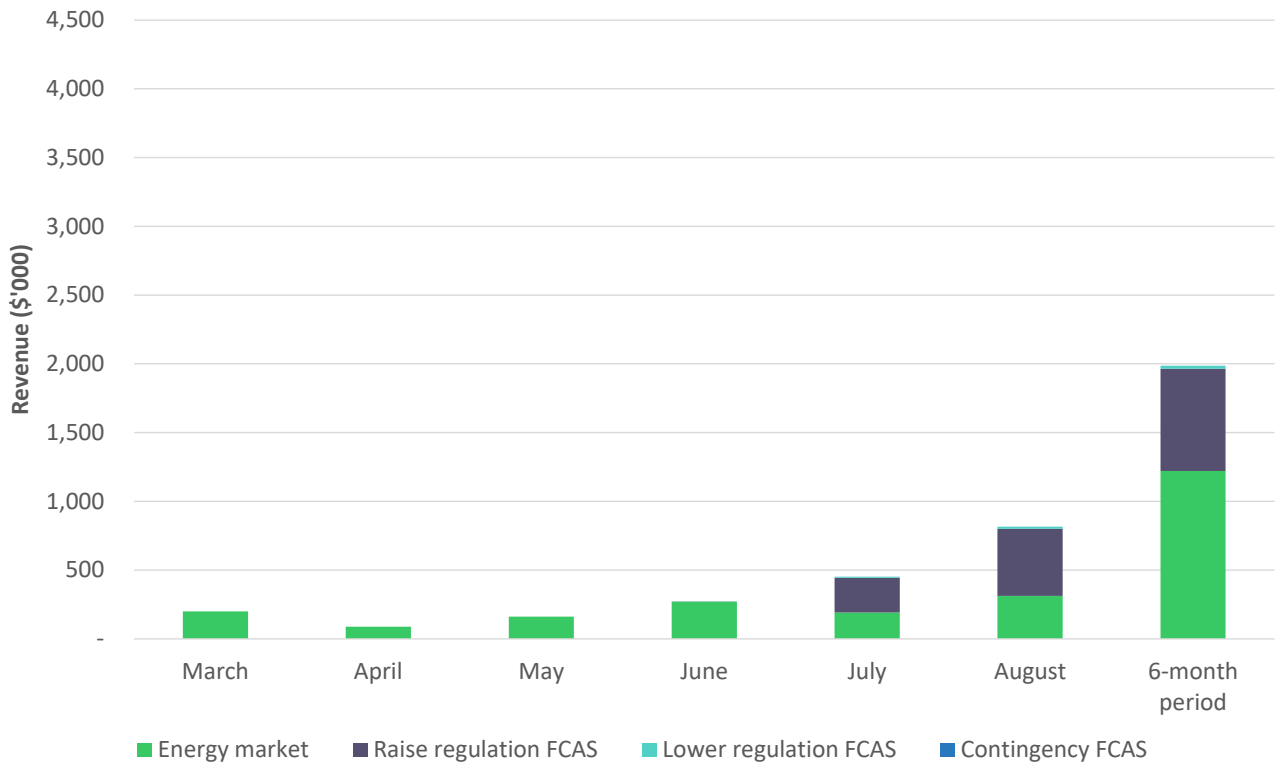
We note that at present the GESS is designed to:

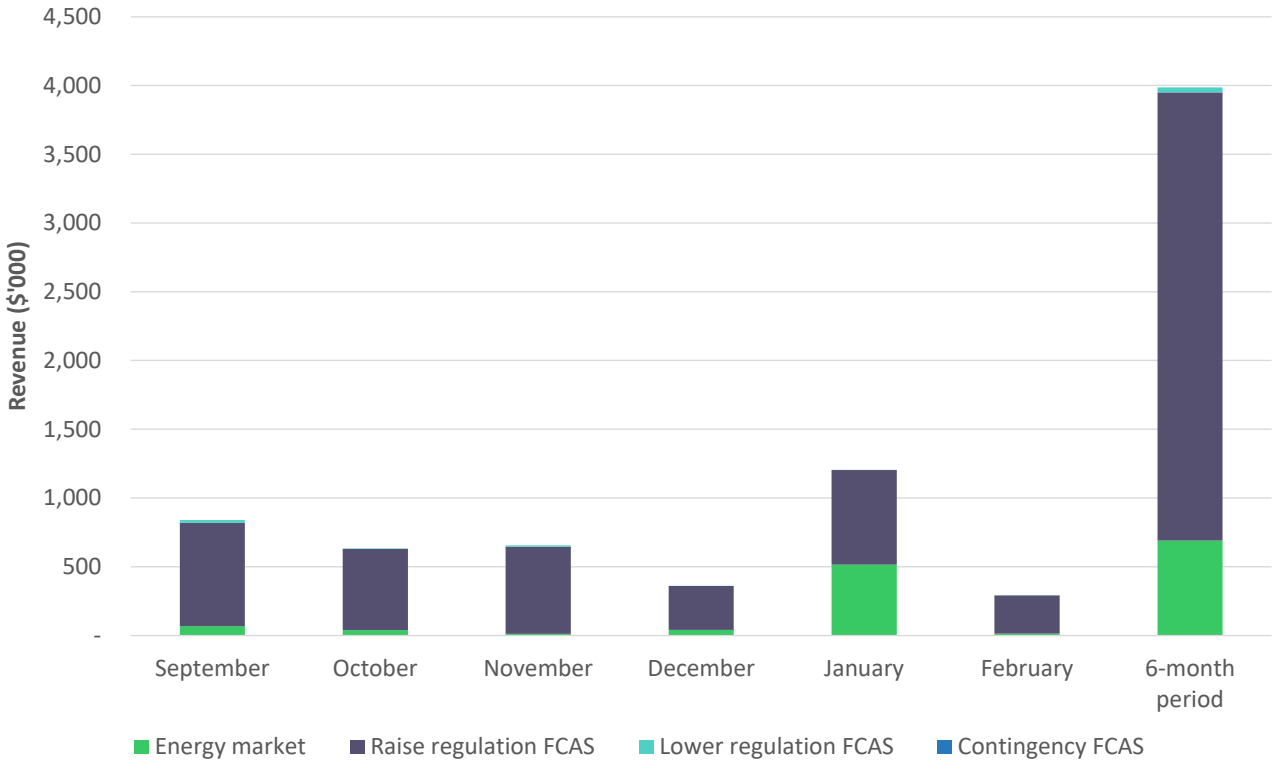
- Maintain its connection point power factor at unity whilst both charging and discharging, and regulate power factor in co-ordination with GSF and in a manner that helps to support network voltages during faults;
- Provide continuous uninterrupted operation within the frequency range 49.5-50.5Hz and in doing so provide support during the period of containment after a generation or load contingency event has occurred and contingency markets have recovered and stabilised the system frequency; and
- Utilise control system settings that are capable of providing for automatic increases or reductions in active power for frequency excursions outside the normal operating frequency band, as well as ensuring power system oscillations are adequately damped.

2.2 Financial performance

Since being registered in the regulation FCAS markets, GESS has performed well from a revenue perspective (see Figure 3). The average generation price for GESS between March and August 2019 was $154/MWh, with an average charging price of $69/MWh. The average generation price for GESS between September 2019 and February 2020 was $173/MWh, with an average charging price of $64/MWh. With less volatile pricing in the energy market, GESS has been able to capture value of FCAS services since July 2019 when it was registered.

Figure 3 Financial performance of GESS

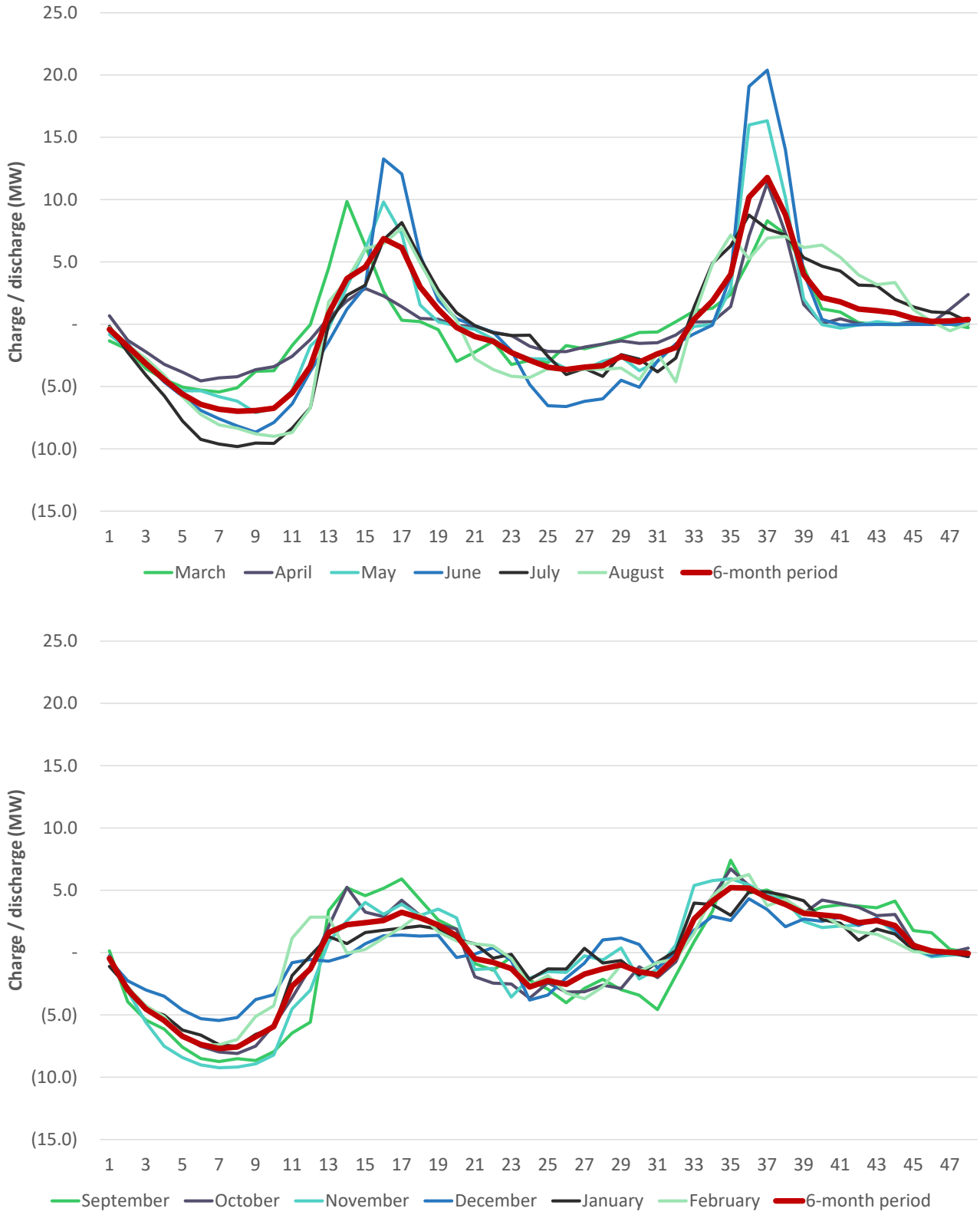




From an energy market perspective, Figure 4 and Figure 5 outline the average operational profile of GESS and trading interval prices in VIC respectively. The operation of GESS has largely followed that of energy market prices with morning and evening peak prices corresponding to two discharge patterns in the day. As discussed further in Section 2.2.2, GESS is predominantly charged in an early morning period, despite incurring network charges in doing so.

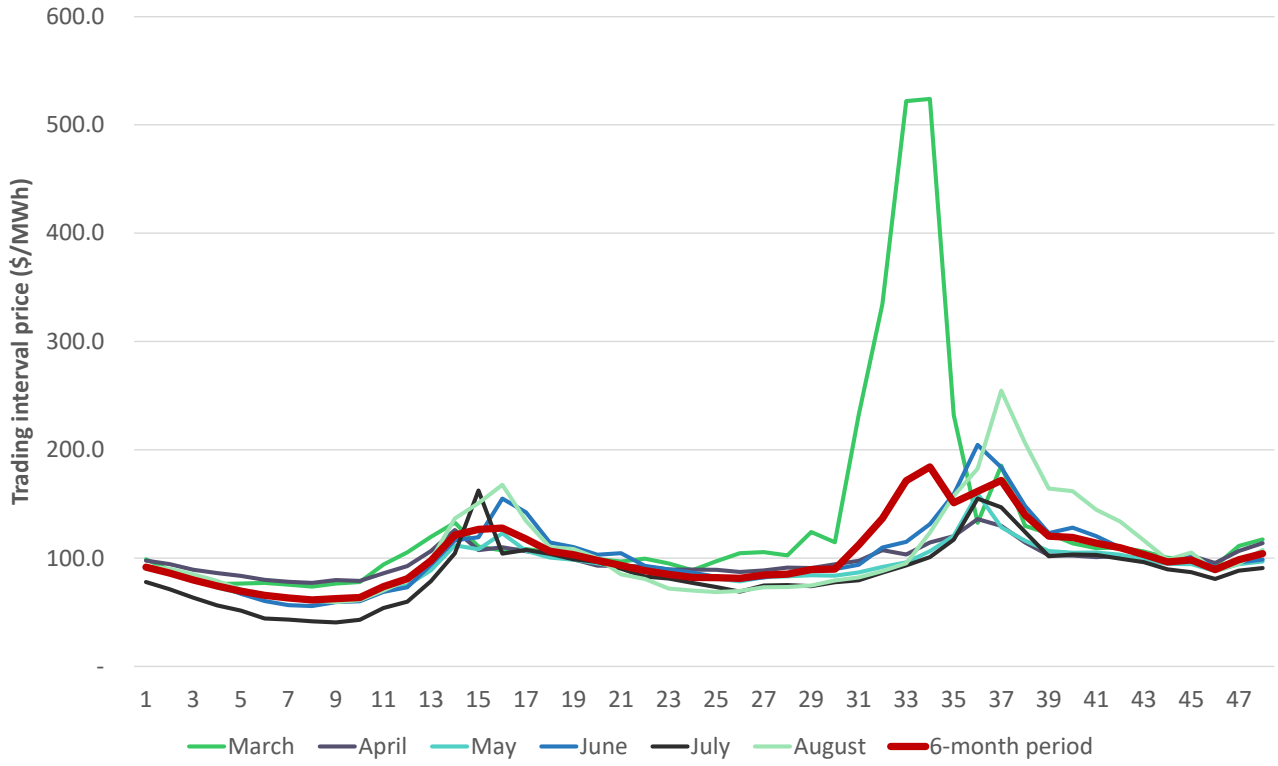
Revenues in the energy market have performed in line with expectations, albeit benefited in large part to a collection of highly volatile days. For instance, ~$485,000 in revenues were received on 31 January 2020 alone due to dispatching at an average price of ~$11,000/MWh between the hours of 3pm and 6pm. These volatile price periods can be seen in the skewed average of prices in the second 6-month period chart of Figure 5.

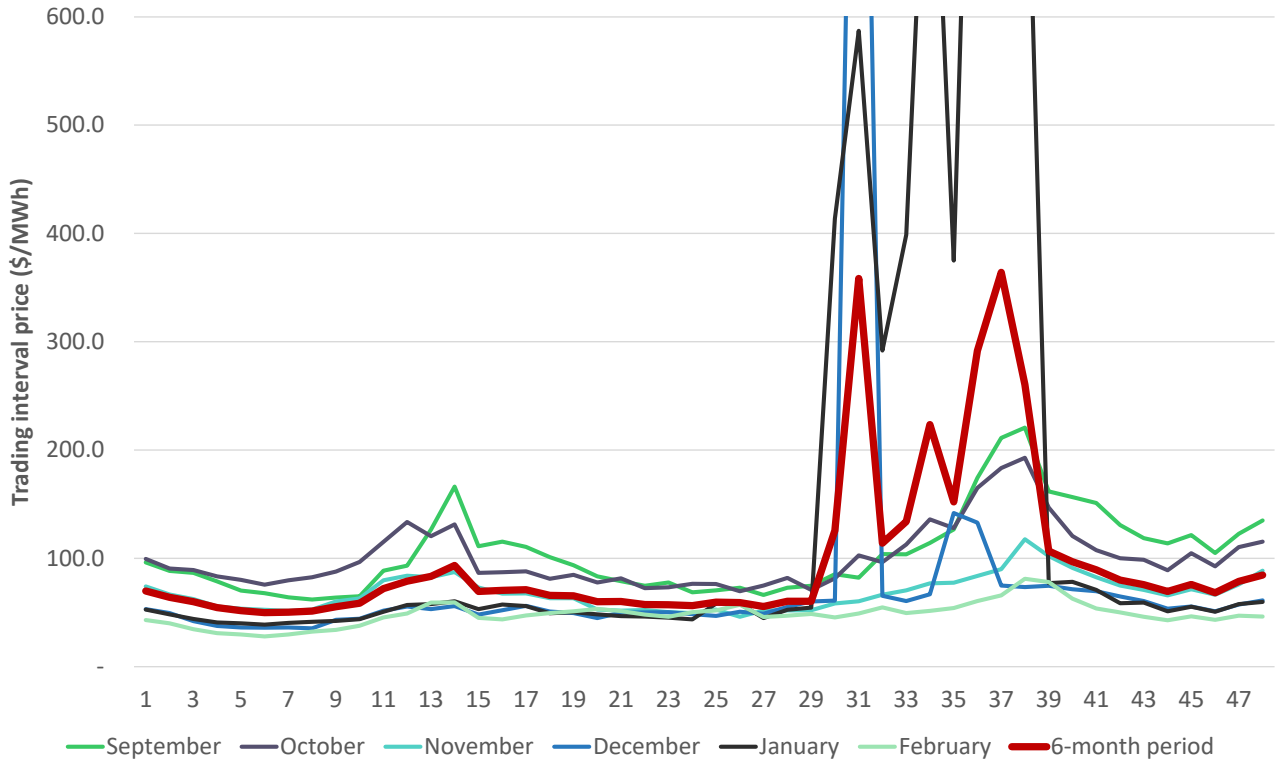
Figure 4 Average GESS operational profile by month[7]



[7] 30-minute periods 1 to 48, where period 1 is commences 12:00am

Figure 5 Average VIC trading interval prices by month[8]

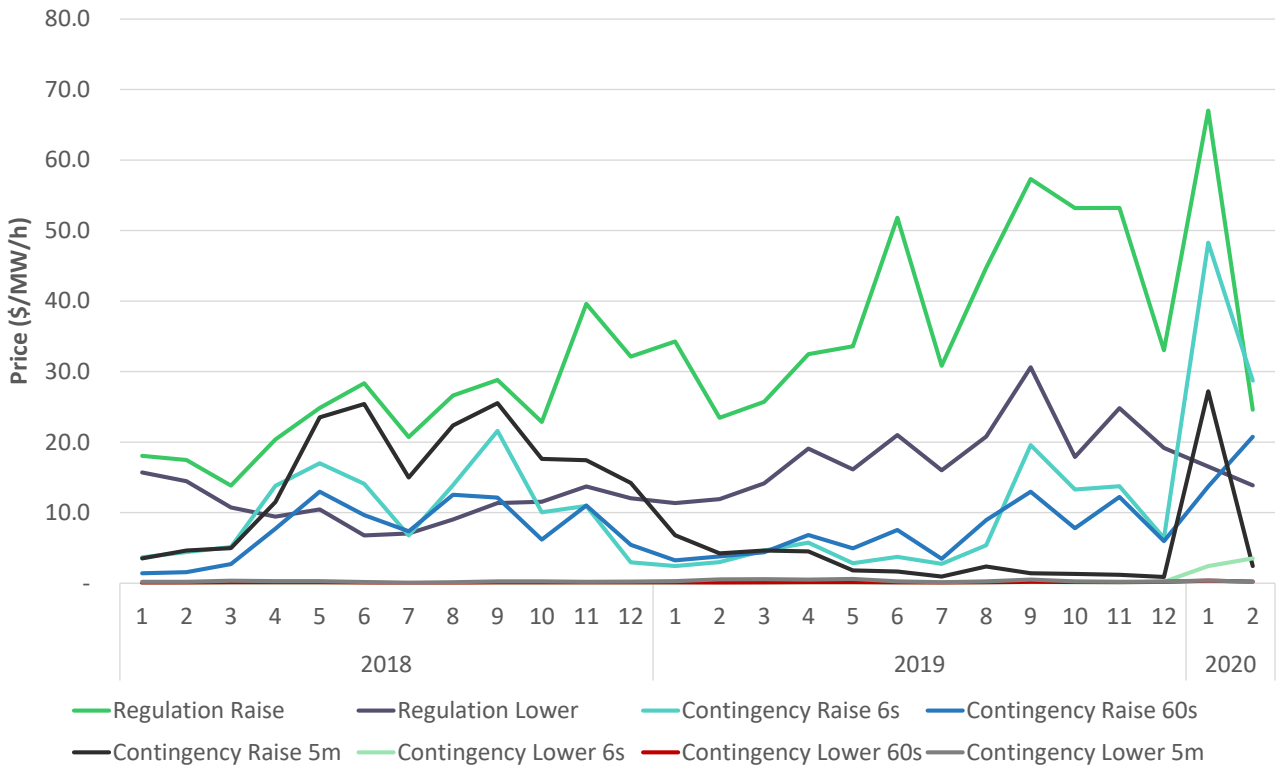




[8] 30-minute periods 1 to 48, where period 1 is commences 12:00am

Since registering for regulation FCAS in July 2019, this revenue stream has been a key contributor to GESS's strong financial performance. GESS has outperformed expectations in regulation FCAS markets, averaging ~$500,000 per month between July 2019 and February 2020. Battery systems are highly effective in the provision of FCAS, which is critical in ensuring the stability of the system. The higher penetration of renewable energy has seen a higher requirement for regulation FCAS, which has resulted in the high FCAS prices recently observed (see Figure 6). While it is unlikely that FCAS prices will remain at the high levels we have seen recently in the long term, revenue stacking is critical to making battery storage systems economic without Government support. The facility has been designed to provide contingency FCAS and it can be enabled and switched on remotely. The high-speed recording equipment is already there to validate its delivered performance. Therefore, at the time of writing, EnergyAustralia was in the process of preparing a registration change application with AEMO to formalise delivery of the contingency FCAS service[9].

Figure 6 Average interval FCAS prices by month and service: January 2018 to February 2020



Coordinated and stacked participation in both energy and FCAS markets is a key feature of battery business cases. The FCAS market is an enablement market which means the battery can be paid on enablement without dispatch. The actual FCAS dispatch is generally 5-10 times less than energy dispatch. This means the same amount of energy stored can provide a longer duration enablement of FCAS than in the energy market. FCAS participation therefore preserves battery cycling and energy degradation limitations, while still ensuring revenue creation. GESS looks to optimise revenue between energy and FCAS markets. During

[9] The process of registration of GESS for FCAS contingency services is influenced by understanding the existing and potential droop settings, confirming interfacility communications protocols, and was de-prioritised until the post contingent voltage oscillations constraints discussed in Section 2.3 had been resolved.

the peak hours, most of its generation is directed toward the energy market, which drives the regulation price up. Otherwise, when the system frequency behaviour cannot meet the operational standard, AEMO increases the demand of regulation FCAS (i.e. volumes procured) to bring the frequency back to the operational standard, which makes this market more profitable.

2.2.1 Marginal and distribution loss factors

The application of losses to reference settlement for GESS back to the RRN is subject to one MLF and two DLFs – one for the Gannawarra Solar Farm Network and one for Powercor's Distribution Network[10] – for its generation and load. Given the short electrical distance between the interface of Powercor's network and GESS's metering point, the AER has determined that a DLF of 1.0 is appropriate for the Gannawarra Solar Farm Network. The MLFs and DLFs for each of the financial years GESS has been in operation within the reporting period are indicated in Table 3.

Table 3 MLF and DLFs for the reporting period

Loss factor	Generation	Load
FY 2018-19		
MLF	1.0070	1.0311
Powercor DLF (DLF_1)	0.9860	0.9860
Gannawarra Solar Farm Network DLF (DLF_2)	1.0000	1.0000
MLF x DLF_1 x DLF_2	0.9929	1.0167
FY 2019-20		
MLF	0.9643	1.0191
Powercor DLF (DLF_1)	0.9951	0.9951
Gannawarra Solar Farm Network DLF (DLF_2)	1.0000	1.0000
MLF x DLF_1 x DLF_2	0.9596	1.0141

2.2.2 Network charges and charging implications

The registered network that provides the interface for GSF and GESS with Powercor is subject to DUOS charges imposed by Powercor. As GESS is the primary source of load, most of these DUOS charges flow through to GESS. The network tariff allocated to the combined system is the Subtransmission class, which is usually reserved for sub-transmission customers (not generators). Prior to the connection of GESS, GSF was subject to the Large Low Voltage tariff class, where maximum overnight loads for auxiliary power consumption were low (in the order of 150kW) so this was not a material cost impost. In contrast, the fixed and demand charges now imposed on GESS are considerable Table 4 outlines the tariffs for each of the ST and LLV Powercor tariff classes applied in 2019 and 2020.

[10] Reference NMI: 6203935735 with DLF code KGS

Table 4 Powercor ST and LLV tariffs for 2019[11] and 2020[12]

Charge	Subtransmission	Large Low Voltage
2019		
Fixed ($ p.a.)	252,000	8,200
Demand ($/kVA p.a.)	24.16	107.83
Peak usage (c/kWh)	2.58	4.19
Off-peak usage (c/kWh)	0.78	2.22
2020		
Fixed ($ p.a.)	262,600	8,800
Demand ($/kVA p.a.)	26.26	119.99
Peak usage (c/kWh)	2.80	4.67
Off-peak usage (c/kWh)	0.85	2.47

The initial views from EnergyAustralia are that overnight prices are still the lowest and there is less certainty in the value of arbitrage if charging during solar hours and discharging across the peak hours. Also, in periods of little to no solar output due to constraints, cloud cover, or maintenance, EnergyAustralia would not be able to use the battery without initiating the high yearly demand charge. EnergyAustralia performed analysis to assess the merits of charging outside of solar hours and found there are diminishing returns past a 10MW yearly demand charge. Therefore, overnight GESS is typically charged between ~12:00-06:00 AEST offsetting this charge with raise regulation services (where stopping or reducing a charge is the equivalent of delivering a raise product). This will continue to be monitored over time, and with further renewable penetration may preference a middle of the day charging regime.

Given the significant network charge costs outlined in Table 4, EnergyAustralia has restricted GESS's charging rate to 10MW, when charging from the grid. Even with this inefficient restriction, the monthly DUOS cost imposed on GESS is around $45-55k. In EnergyAustralia's opinion, this is an opportunity to improve the economics of distribution connected battery storage projects as energy storage facilities are not subject to network charges if connected to the transmission network in Victoria because they tend to use the network at times that are more helpful than a hindrance so represents a more cost reflective and usage based approach.

Table 5 summarises the evolution of revenues and costs and the financial performance of GESS for its first six months of operations with Table 6 summarising its second six months of operations.

[11] https://media.powercor.com.au/wp-content/uploads/2018/12/20154518/Network-Tariff-Schedule-2016-2019.pdf
[12] https://media.powercor.com.au/wp-content/uploads/2019/11/13093923/Powercor-Pricing-Proposal-2020.pdf

Table 5 Summary of GESS financials from March to August 2019

Source of revenue / charge	March	April	May	June	July	August	6-month period
Pool revenue	198,739	88,140	162,017	268,845	191,702	311,549	1,220,992
Charging costs	-82,671	-62,466	-94,415	-134,690	-113,021	-170,692	-657,955
Ancillary service revenue	-	-	-	2,235	260,284	503,544	766,063
DUOS charges	-45,313	-43,713	-47,460	-47,899	-50,937	-51,745	-287,067
Market fees	-358	-264	-448	-570	-1,424	-1,532	-4,596
Net	**70,397**	**-18,303**	**19,694**	**87,921**	**286,604**	**591,124**	**1,037,437**

Table 6 Summary of GESS financials from September 2019 to February 2020

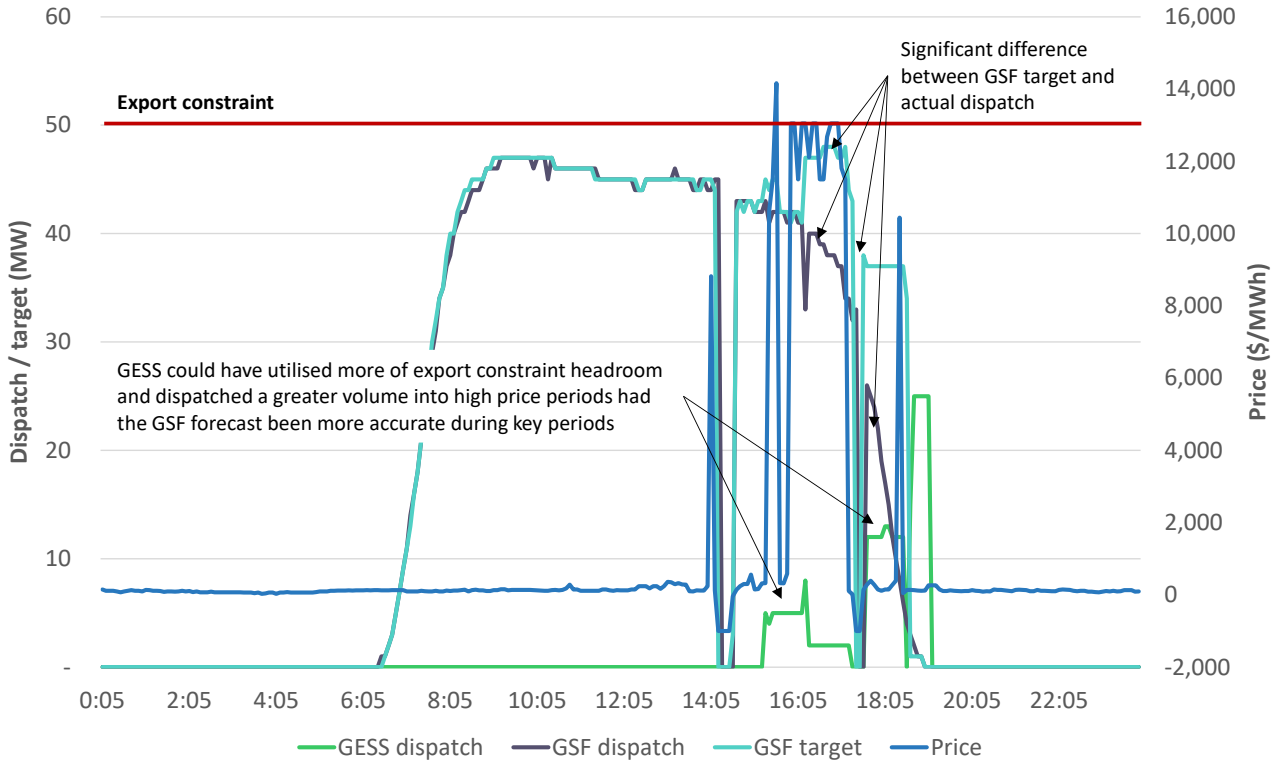
Source of revenue / charge	September	October	November	December	January	February	6-month period
Pool revenue	246,550	191,668	123,906	99,226	603,946	79,187	1,344,484
Charging costs	-178,588	-152,496	-111,891	-57,987	-88,965	-64,869	-654,796
Ancillary service revenue	771,669	594,020	643,713	320,426	689,520	277,917	3,297,264
DUOS charges	-51,015	-49,181	-49,698	-45,709	-51,720	-50,625	-297,947
Market fees	-1,432	-1,444	-1,347	-1,235	-1,184	-1,312	-7,954
Net	**787,184**	**582,567**	**604,684**	**314,721**	**1,151,597**	**240,299**	**3,681,051**

2.3 Constraints on operation

As described in Section 1.4, GESS is located within a registered network that is shared with GSF. This registered network is in-turn connected to Powercor's distribution network. The combined connection point of GSF and GESS has a rating of 50MW to which GSF has priority access. Whilst the shared grid connection point and capacity was efficient from a design perspective, it does mean that GESS is effectively constrained to utilising headroom in this connection point from unutilised solar output, which therefore requires accurate real-time knowledge of GSF's output and what headroom is available for GESS.

One issue that was highlighted on 1 March 2019 was the inaccuracy of the solar forecast used by AEMO, which reduced the efficiency of GESS's dispatch. On that day, there was around 10MW of battery capacity which could have been dispatched at the Maximum Pricing Cap, but GESS's output was inadvertently restricted due to inaccurate forecasting of GSF (see Figure 7). This came at an opportunity cost of ~$150,000 of lost revenues on this particular day. These inaccuracies should be improved with the introduction of more sophisticated self-forecasting.

Figure 7 Impact of forecast error on GESS dispatch: 1 March 2019



It has been challenging to optimise GESS's dispatch using a default bid as GSF's output is quite variable, requiring a conservative bid to be submitted the day prior based on initial GSF forecasts. Due to compliance requirements, EnergyAustralia tends to bid a volume of GESS generation based on the highest GSF forecast until closer to the dispatch timeframe, particularly where higher demand / revised forecasts are evident. Traders will then rebid GESS to fully optimise its generation based on the more accurate GSF forecast. Also, as GSF's output reduces quickly once the sun sets, it is difficult to fully optimise the half hours between 18:00-20:00 AEST as there would be missed 5-min periods where GSF would be producing more / less than forecasts. These challenges were most evident through early March (EnergyAustralia's contract start) when GSF's output was at its highest. Recently these challenges were alleviated while there was a 25MW constraint placed on GSF's output from 13/09/2019 to the end of the reporting period (invoked constraint equation V_GANWRSF_FLT_25 implemented by AEMO to manage post contingent voltage oscillations), which meant that the battery has had unrestricted access to the network.

EnergyAustralia is actively looking to upgrade its bidding system, which will seek to include an ability to utilise API calls. This will allow a direct feed of the solar farm forecast to limit the battery generation prior to each dispatch interval, meaning there is improved potential to fully utilise the transformer headroom while still allowing EnergyAustralia to remain compliant within the bidding rules.

TECHNICAL PERFORMANCE

Edify™

3 Technical performance

3.1 Technical performance

3.1.1 Cycle performance

GESS has operated on average close to one cycle per day since the beginning of March, for a total charge energy of 9,271 MWh and discharge energy of 7,991 MWh for the 6-month period to August 2019, and 10,522 MWh and 9,022 MWh for the 6-month period to February 2020. The cycle rate was slightly lower through the earlier and winter months, with increased activity following the registration for regulation FCAS in June and the shoulder months leading into summer. Table 7 summarises the charge and discharge cycle outcomes for the 6-month period to August 2019 with Table 8 summarising the 6-month period to February 2020.

Table 7 Charge and discharge cycle summary: March to August 2019

Parameter	March	April	May	June	July	August	6-month period
Charge energy (MWh)	1,081	793	1,357	1,758	1,979	2,304	9,271
Discharge energy (MWh)	935	688	1,199	1,528	1,669	1,972	7,991
Cycle count	19	14	24	31	33	39	160
Cycles per day	0.6	0.5	0.8	1.0	1.1	1.3	0.9

Table 8 Charge and discharge cycle summary: September 2019 to February 2020

Parameter	September	October	November	December	January	February	6-month period
Charge energy (MWh)	2,251	1,843	2,000	1,319	1,599	1,510	10,522
Discharge energy (MWh)	1,912	1,599	1,641	1,155	1,397	1,317	9,022
Cycle count	38	32	33	23	28	26	180
Cycles per day	1.3	1.0	1.1	0.7	0.9	0.9	1.0

As Figure 8 indicates, the round-trip efficiency for GESS averaged 86.2% for the 6-month period to August 2019 and 85.7% for the 6-month period to February 2020, fluctuating in a band between ~82-88%. Note this round-trip efficiency calculation is made at the facility revenue meter based on observed aggregate energy bought and sold into the market (i.e. aggregate discharge / aggregate charge). It is therefore inclusive of balance of system losses and has not been adjusted for MLF. This is a different and more approximate calculation than what would be undertaken for formal performance testing, which would stipulate standard test conditions, including the power rating of the charge and discharge, and a defined period of time between conducting the charge and discharge.

Figure 8 Round-trip efficiency

3.1.2 Availability

The availability for GESS has also been high throughout the reporting period, with greater than 97.8% inverter block availability recorded in all months, with the exception of March (see Table 9 and Table 10). Note: the lower availability in March is not an accurate reflection of actual availability as there were errors in the SCADA data collection following a software update for a couple of days during this month, which have not been adjusted out.

Table 9 Inverter block availability: March to August 2019

Parameter	March	April	May	June	July	August	6-month period
Availability	93.8%	99.8%	100.0%	99.9%	100.0%	100.0%	98.9%

Table 10 Inverter block availability: September 2019 to February 2020

Parameter	September	October	November	December	January	February	6-month period
Availability	100.0%	99.2%	100.0%	98.8%	97.8%	99.3%	99.2%

3.2 Safety and environmental performance

GESS recorded no safety or environmental incidents in the 6-month period to August 2019 nor the 6-month period to February 2020. This is not unexpected due to the nature of the facility as well as the workplace health and safety policies adopted on site. As a company Edify is always targeting zero incidents for our sites.

During the design of the battery system, elimination of risk has been adopted wherever possible, which is the first principal of risk control. This has been done by eliminating the need for intervention by staff in the operation of the facility as far as possible. The site is designed for fully unmanned operations meaning that staff only attend site to respond to faults or to conduct preventative maintenance inspections. This avoids the majority of safety and environmental risk with the facility.

Where staff are required to go to site, the operations and maintenance contractor responsible for oversite of safety on the site has safety procedures in line with best industry practice. This includes ensuring that correct isolations are in place for works to be undertaken and using lock-out procedures to prevent unintended re-energisation. The O&M contractor reviews the work plans of any Tesla staff coming to site to maintain the batteries which are maintained under a services agreement.

The safety record of the facility is also in large part to the inherent safety architecture aspects of the battery system that includes:

- Individual cell testing prior to module assembly to ensure flawed cells are not introduced into the battery system;
- Pods (collection of cells) are fully sealed to prevent thermal spread and have dedicated management systems that monitor individual cells to ensure they are operated within safe parameters;
- Packs (racks of 16 pods) are contained in weather-proof steel enclosures with monitoring and operation optimised to reduce the risk of cascading failure of pods;
- Compliance with national and international safety standards; and

- Exceedance of standards related to fire safety and propagation resistance to thermal runaway within individual cells.

Tesla technicians perform all preventative maintenance and inspections of the battery system which ensures that any issues are identified before they become a safety or environmental concern.