hepburn wind community energy

Hybrid Planning Permit | Attachment 3

BESS Feasibility Study

Title	Hepburn Solar Farm BESS Feasibility Study
Customer	Hepburn Community Wind Park Co-Operative Ltd
Contact	Taryn Lane
Document No.	PP207530-AUME-T-03-B
Issue	B
Classification	Customer's discretion
Author	Daniel Shen
Checked	Faraz Mirzaagha
Approved	Christian Peake

Issue:	Date:	Summary
A	29/07/2020	Initial Draft
B	06/08/2020	Updated Re-electrify price

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1 EXECUTIVE SUMMARY

DNV GL Australia Pty Ltd (DNV GL) has been contracted by Hepburn Community Wind Park Co-Operative Ltd (the Customer) to conduct an indicative BESS feasibility study, to be connected with the proposed Hepburn Solar Farm. This document is issued to the Customer pursuant to DNV GL proposal PP207530-AUME-VO-003-A dated 17 March 2020.

The Hepburn Solar Farm will experience significant power curtailment losses, as the project has a high DC/AC ratio and a restricted grid connection capacity. Installing a BESS (Battery Energy Storage System) could recover this otherwise lost energy and allow additional revenue from providing FCAS services. DNV GL investigated two BESS options (Tesla Powerpack and Re-electrify) and sized them based on the potential excess solar generation. A battery operational logic based on a target spot market energy to control discharge was modelled using a time series approach. Using historical prices, wind generation and modelled solar generation data between the period 2012-2019, DNV GL modelled the potential annual revenues for each BESS option.

The target price yielding the highest potential annual revenue for each year and each BESS option is presented below.

Table 1 Summary of indicative revenue estimates

Year	Tesla Powerpack 8.6MWh/4.8MW				Re-electrify 8.4MWh/2.5MW			
	Target energy price $/MWh	Potential Annual Revenue $/year	FCAS proportion	Energy trading proportion	Target energy price $/MWh	Potential Annual Revenue $/year	FCAS proportion	Energy trading proportion
2012	0	$116,069	47%	53%	20	$87,074	32%	69%
2013	40	$82,887	47%	53%	40	$66,117	30%	69%
2014	20	94,719	61%	39%	20	$69,332	44%	57%
2015	30	$86,392	62%	38%	30	$61,094	44%	55%
2016	40	$221,187	80%	20%	40	$138,723	69%	32%
2017	30	$456,837	84%	16%	20	$272,016	73%	27%
2018	90	$608,290	81%	19%	20	$371,363	68%	32%
2019	100	$445,796	52%	48%	100	$337,883	35%	65%

It should be noted that these annual revenue results are based on a range of assumptions related to the battery operation logic and power price, as historical power prices have been used in the analysis however during operation only a price forecast will be available (for example next 30min forecast).

Further work is required to determine more realistic and optimal battery behaviour, including degradation considerations, using historic forecast prices rather than actual and battery charging logic. It should also be noted that energy prices are volatile and subject to policy changes, particularly in the FCAS market, and therefore may be different in the future.

DNV GL considers the results presented to be indicative and further work is required to inform investment and final design.

2 BACKGROUND

2.1 Motivation

The proposed Hepburn Solar Farm has high modelled clipping losses due to limitations from both the inverter AC capacity and grid point of connection (POC) requirements. Therefore, there is potential for a battery energy storage system (BESS) to utilise this otherwise lost energy. The BESS can realise additional revenue from trading stored energy and participate in the FCAS market. The Customer is currently interested in two BESS options: Tesla Powerpack and Re-electrify. DNV GL have modelled the potential annual revenue of each option over various years and various capacities.

2.2 Modelling Period and Relevant Markets

From 2012 to 2019, there is an overlap period of integer years between the historical Hepburn Wind Farm and modelled solar farm generation. The modelling study considers the historical spot market energy prices, FCAS prices, combined modelled wind and solar generation over this period from PP207530-AUME-T02-A report prepared by DNV GL.

The addition of a BESS will increase revenue from energy trading in the spot market as well as potentially taking advantage of higher prices. The BESS can generate revenue from participation in the FCAS markets. Assuming that the control system facilities requirements [1] are fulfilled. There are 8 FCAS markets in total, with two belonging to regulation and six to contingency services. Regulation service providers are subject to AEMO's instruction to maintain the grid frequency within the normal operating band of 49.85Hz to 50.15Hz. When the grid frequency exceeds this band, a credible contingency event can be triggered, and relevant contingency providers may be dispatched to return the frequency back to the normal band. The contingency FCAS market is made up of three raise and three lower services of various response times (6 seconds, 60 seconds and 5 minutes). Raise contingency participants will either discharge power or reduce load to increase the system frequency. Lower contingency participants will either charge power or increase the load to reduce the system frequency. A summary of each FCAS market category along with the average trading interval prices for Victoria between 2012 to 2019 is presented below. Note that the FCAS prices may vary significantly year to year and so the range of average trading interval prices by year is presented to be indicative of potential value.

Table 2 Overview of FCAS Market Services and average trading interval price for Victoria between 2012-2019

FCAS Market Category	Frequency Range for Enablement	Range of Average Annual Trading Interval Prices ($/MW Enabled/ hour)
Regulation Raise	<50Hz	1.26-39.50
Regulation Lower	>50Hz	0.62-23.67
Contingency Raise 6 sec	<49.85	0.93-12.6
Contingency Raise 60 sec	<49.85	0.61-7.58
Contingency Raise 5 min	<49.85	1.11-15.52
Contingency Lower 6 sec	>50.15	0.02-0.06
Contingency Lower 60 sec	>50.15	0.04-0.16
Contingency Lower 5 min	>50.15	0.23-0.74

While the regulation raise market has the highest average price over the modelled period, it is difficult for a BESS, particularly of the sizes considered in this study, to be an efficient provider of regulation services. Since the frequency distribution in the NEM is largely within the normal band of

49.85-50.15, as shown in Figure 1, the BESS may be frequently required to discharge which is likely to be uneconomical since it will affect revenue from energy trading and the constant cycling will shorten the lifetime.

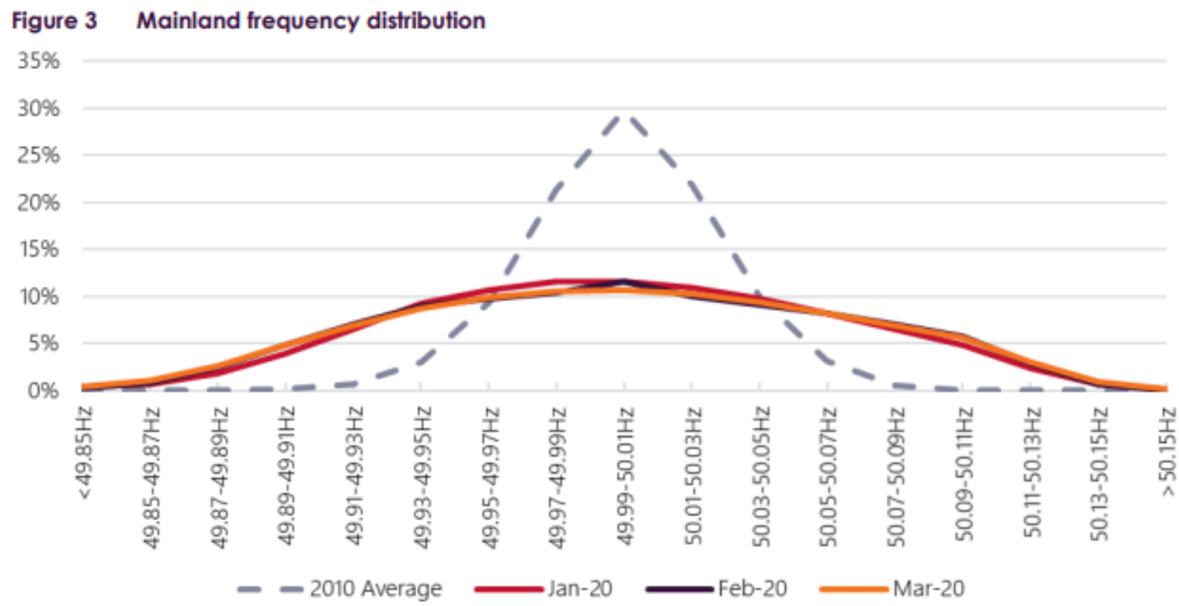

Figure 1 Distribution of frequency in the NEM over the first quarter of 2020 [2]

The BESS is able to simultaneously bid into either all 3 raise or lower contingency markets as shown in Table 2. After reviewing the FCAS prices in the past 8 years, it is evident the raise market presents a more profitable option due to high demand low supply. The contingency events are also fairly rare, and given the uncertainty in actual dispatch, it is likely that the BESS is able to provide raise services for over a significant period. This is particularly relevant for this Project since, during the winter periods, where there is reduced excess solar generation to charge the BESS, FCAS will be the primary source of revenue as shown below for the example year of 2018. It should also be noted that the BESS can load shift higher amounts of excess solar to capture higher energy spot prices during peak demand periods such as the late afternoon during summer.

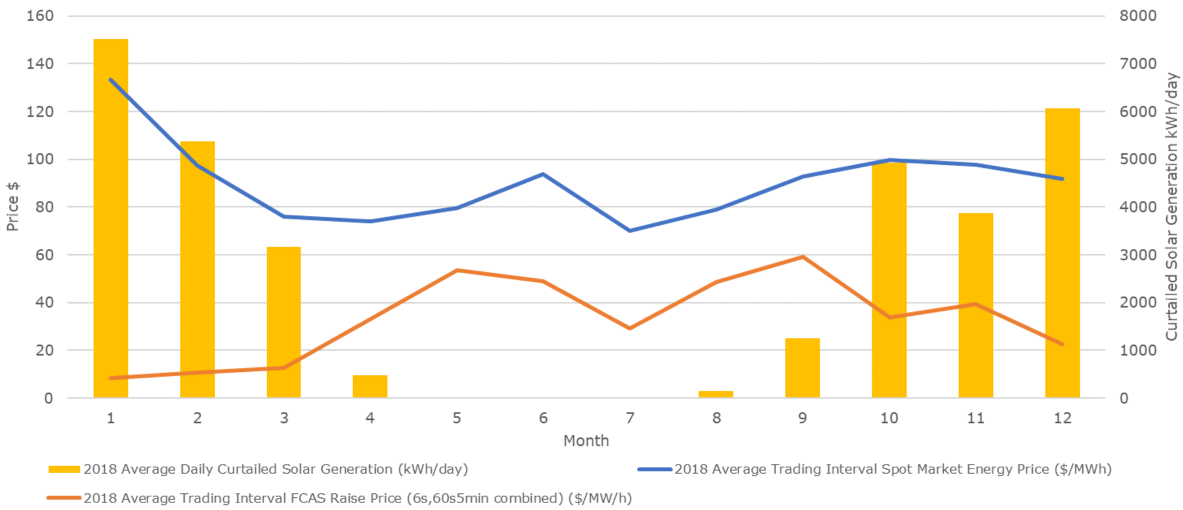

Figure 2 Average FCAS, spot market prices and available daily solar curtailment by month over 2018 from modelled solar generation from PP207530-AUME-T-02-A

Therefore, the potential annual revenue for a BESS will be modelled using historic spot market and all 3 FCAS raise market prices.

3 METHODOLOGY AND ASSUMPTIONS

3.1 BESS Configuration

A BESS can be either DC or AC coupled, which refers to the way it is being charged from the PV source. This is important as it affects the way it is connected to the grid. Given the current POC restraints, an AC coupled BESS would require additional grid connection studies as the overall system AC capacity and hence fault current would increase. This is also likely going to incur additional capital costs required for network augmentation. The DC coupled option would be in general simpler to implement as the current POC conditions will remain consistent. The current solar inverter (SMA SC-2500) also has an option to allow for DC coupled storage systems.

Therefore, we will be modelling the BESS as a DC coupled system.

3.2 Modelling Approach

The BESS operation was modelled for each trading interval (30 minute) of every year over the 2012 to 2019 period. The available excess generation for charging, and the available discharge capacity, was calculated for each time interval depending on the combined wind, solar generation and available solar inverter export capacity at each timestamp with consideration to the POC requirements [3] (7.8MVA, underexcited 0.87 Power Factor). Based on the charge state of the battery and spot market energy price, a logic was implemented to dictate BESS operations. This logic is comprised of the following rules:

- The BESS can only charge or discharge but not at the same time during each time interval
- The BESS will only charge from excess solar generation
- The BESS can provide either FCAS or trade energy but not both during each time interval. When the BESS is providing either of these services, it is considered to be discharging, i.e. no charging can occur during this period.
- In order to bid in the FCAS markets, the BESS needs to have a minimum charge level to account for dispatch in case of contingency events
- This minimum charge level depends on the length of time required by dispatch for the FCAS bid as defined in AEMO's rules [1]
- A target energy price is set at which the BESS will discharge if the spot market price is at or exceeds this level, provided that the BESS has a charge level greater than the minimum charge level.
- The BESS discharge is limited by the lower of the available export limit, available BESS charge and BESS power capacity
- The BESS FCAS bid is limited by the lower of the available export limit, and maximum BESS FCAS bid capability as defined by AEMO's requirements for BESS in contingency FCAS [4]
- The priority of BESS operations provided that required conditions are met are as follows:
    1. Discharge energy at or above target price
    2. Charging excess solar generation
    3. Bidding FCAS

Target energy prices in the range of $0/MWh to $100/MWh in intervals of $10/MWh will be tested. An example of this modelled BESS logic operation during a period in 2016 is provided in Figure 3 for a target price of $40/MWh.

Date/Time	Wholesale Price $/MWh	FCAS Raise Price $/MW/hour	Available Discharge for BESS kW	Available Charge for BESS kW	BESS Charge Level kWh	Charge Amount kWh	Charge Mode	Sell Energy?	Bid FCAS?	Discharge Amount kWh	FCAS bid kW	New BESS Charge level kWh	Revenue $
15/12/2016 5:00	$ 25.65	$ 9.44	3690.35014	0	2812.752342	0	DISCHARGE	FALSE	TRUE	0	2141.18	2812.75234	$ 10.11
15/12/2016 5:30	$ 28.52	$ 8.62	3092.189544	0	2812.752342	0	DISCHARGE	FALSE	TRUE	0	2141.18	2812.75234	$ 9.23
15/12/2016 6:00	$ 39.57	$ 8.26	2494.028948	0	2812.752342	0	DISCHARGE	FALSE	TRUE	0	2141.18	2812.75234	$ 8.84
15/12/2016 6:30	$ 46.09	$ 5.88	1726.49433	0	2812.752342	0	DISCHARGE	TRUE	FALSE	759.657505	0	1949.50518	$ 35.01
15/12/2016 7:00	$ 39.59	$ 5.50	958.9597115	0	1949.505177	0	DISCHARGE	FALSE	TRUE	0	958.96	1949.50518	$ 2.64
15/12/2016 7:30	$ 40.92	$ 8.06	479.4798557	129.6985	1949.505177	0	DISCHARGE	TRUE	FALSE	210.971137	0	1709.76525	$ 8.63
15/12/2016 8:00	$ 52.53	$ 7.23	0	259.397	1709.765249	114.1347	CHARGE	FALSE	FALSE	0	0	1823.89993	$ -
15/12/2016 8:30	$ 42.61	$ 5.58	0	810.642092	1823.899929	356.6825	CHARGE	FALSE	FALSE	0	0	2180.58245	$ -
15/12/2016 9:00	$ 41.35	$ 5.05	0	1361.88718	2180.58245	599.2304	CHARGE	FALSE	FALSE	0	0	2779.81281	$ -
15/12/2016 9:30	$ 41.34	$ 4.98	0	1838.03031	2779.81281	808.7333	CHARGE	FALSE	FALSE	0	0	3588.54615	$ -
15/12/2016 10:00	$ 40.83	$ 4.87	0	2314.17343	3588.546146	1018.236	CHARGE	FALSE	FALSE	0	0	4606.78246	$ -
15/12/2016 10:30	$ 38.57	$ 4.45	0	2529.68305	4606.782456	1113.061	CHARGE	FALSE	FALSE	0	0	5719.843	$ -

Figure 3 Sample of modelled BESS logic

It should be noted that in practice, a dedicated software solution is required to implement such logic as bids will require to be resubmitted for every dispatch interval through the online EMMS portal [5].

Some additional assumptions used in the modelling:

- The FCAS bid from the BESS will always be enabled
- The BESS bidding in both the energy and FCAS markets is small relative to the system that prices will not be affected

3.3 Model Inputs

The following table outlines the assumed technical inputs for the Tesla Powerpack and Re-electrify chosen BESS models. See appendix for datasheets supporting some of the assumptions.

Table 3 Technical Model Inputs for BESS options

Parameter	Tesla Powerpack	Re-electrify
Energy Capacity kWh/unit	232	120
Power Capacity kW/unit	130	36
Round Trip Efficiency	88%	90%
Droop[1]	1.7%	1.7%
Max FCAS bid[1] kW/unit	53.5	14.8
Minimum charge level for Max FCAS bid[2] kWh/unit	20.3	5.5
Estimated land footprint m^2/unit	2.6	1.9

1. Minimum allowable droop and consequential max FCAS bid power based on AEMO's specifications [4]
2. Based on sufficient charge for 2 contingency FCAS discharges for all 3 markets in accordance to AEMO rules [1]

BESS degradation has not been modelled as this will be dependent on multiple factors such as climate, charge/discharge regime and additional documentation to be provided by the manufacturer.

The BESS will be modelled for each year by treating each year as year 1 of operation of the BESS rather than if the BESS was to operate continuously across the entire 2012-2019 period. This will also help support the no degradation assumption since BESS degradation will be relatively negligible over a single year.

No additional auxiliary loads attributed to BESS operation is considered.

3.4 BESS Sizing

As a starting point, the BESS will be sized based on the average daily solar curtailment, which reflects how much energy could be stored. Across the 8 years, the month of January has the highest average daily solar curtailment at around 7.5MWh. Accounting for the round-trip efficiency, this results in the following sizes for each BESS option:

- 37 units of Tesla Powerpack – 8.6MWh/4.8MW 96.2m^2 estimated footprint
- 70 units of Re-electrify – 8.4MWh/2.5MW 133m^2 estimated footprint

For each of these configurations, various target energy price logics will be tested to determine the potential annual revenues.

4 RESULTS AND DISCUSSION

4.1 Model Results

The target energy price resulting in the highest potential annual revenue for each modelled year and BESS option is presented in Table 4 below.

Table 4 Optimal target energy price and associated potential annual revenues

Year	Tesla Powerpack				Re-electrify			
	Target energy price $/MWh	Potential Annual Revenue $/year	FCAS proportion	Energy trading proportion	Target energy price $/MWh	Potential Annual Revenue $/year	FCAS proportion	Energy trading proportion
2012	0	$116,069	47%	53%	20	$87,074	32%	69%
2013	40	$82,887	47%	53%	40	$66,117	30%	69%
2014	20	94,719	61%	39%	20	$69,332	44%	57%
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2018	90	$608,290	81%	19%	20	$371,363	68%	32%
2019	100	$445,796	52%	48%	100	$337,883	35%	65%

The optimal target energy price and potential annual revenues vary significantly between the years, which is reflective of the variability of spot market energy and FCAS market prices in this period. The significant increase in revenues between 2016-2019 is reflected in the much higher energy and FCAS prices seen in Figure 4. FCAS is also a significant driver in the annual revenue, particularly during the 2016-2018 period.

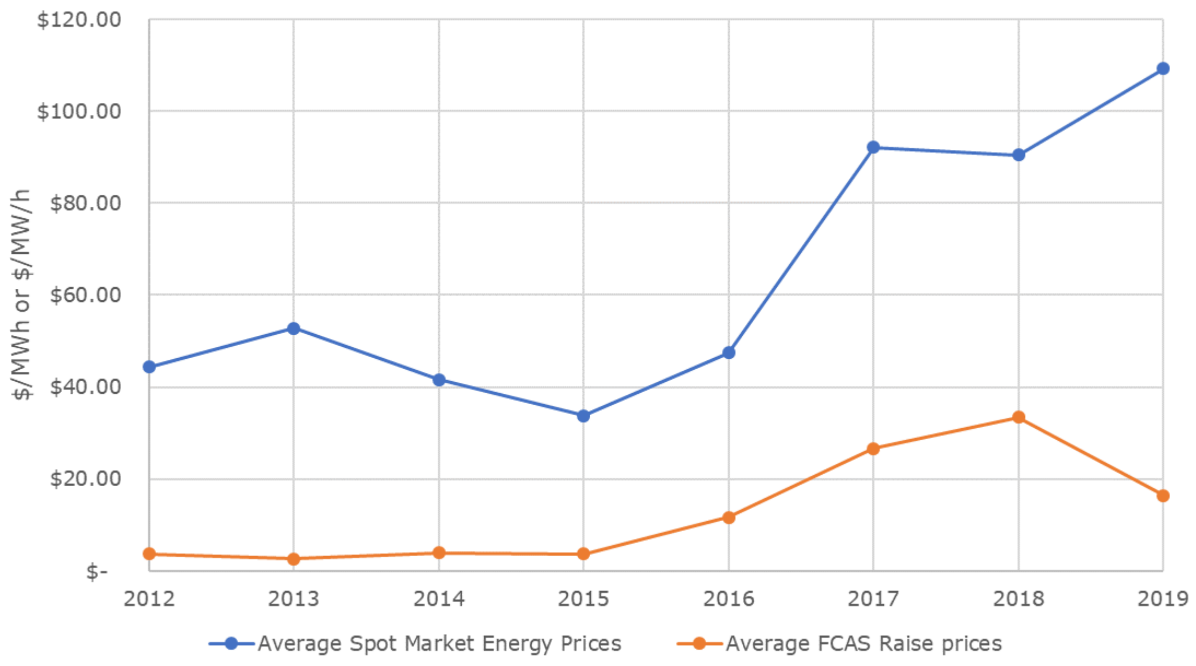

Figure 4 Historic average spot market energy and FCAS prices

4.2 High-level Costing estimates

Converting the US retail price for the modelled Tesla Powerpack [6] to AUD comes to $242,000 per unit which is around $1,040/kWh. This amount translates to $8,954,000 for the Tesla Powerpack option which consisted of 37 units.

Re-electrify option uses recycled Li-ion batteries and hence is significantly cheaper at $64,000 AUD per unit [7]. This results in $4,480,000 for the modelled 70 units option.

Note that the Tesla cost includes a battery inverter which will also be required in the Re-electrify option. There may be potential to drive down this cost given the scale of the project.

DNV GL have based this analysis on generic publicly available pricing and assumption, therefore it is recommended to obtain more accurate pricing directly from the suppliers. More accurate pricing information will also help to improve future optimisation studies.

4.3 Risks and Future Outlook

Energy prices had risen significantly since 2016 due to a variety of factors including the retirement of significant fossil fuel generation capacity and higher gas prices. These supply side changes are likely to be long lasting with further fossil fuel retirements such as the upcoming Liddell station in NSW scheduled for 2022 likely to keep prices high.

The FCAS market will have much more uncertainty in the future. It is likely that prices will decrease in the near future with the recent rule change from AEMC requiring mandatory frequency response for all dispatched generators [8]. The aim is to address the recent worsening of the grid frequency distribution and attempting to bring it back to early 2000 levels as seen in Figure 5.

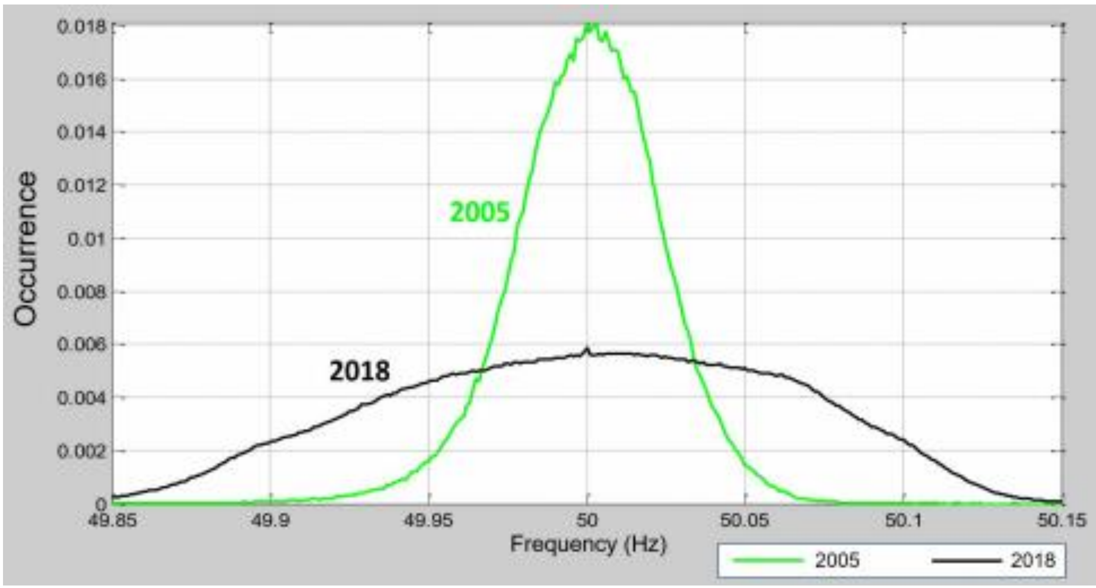

Figure 5 NEM mainland frequency distribution 2018 and 2005 [8]

This change in the frequency distribution will reduce the FCAS contingency market size by reducing the proportion of frequency of contingency events and lowering the contingency capacity requirements.

One positive development is the downward trend in storage costs. Battery pack costs are forecast to continue falling towards 2030 as shown in Figure 6. These forecast curves were based on various Li-ion battery forecast studies from Roskill, NREL, Bloomberg and others.

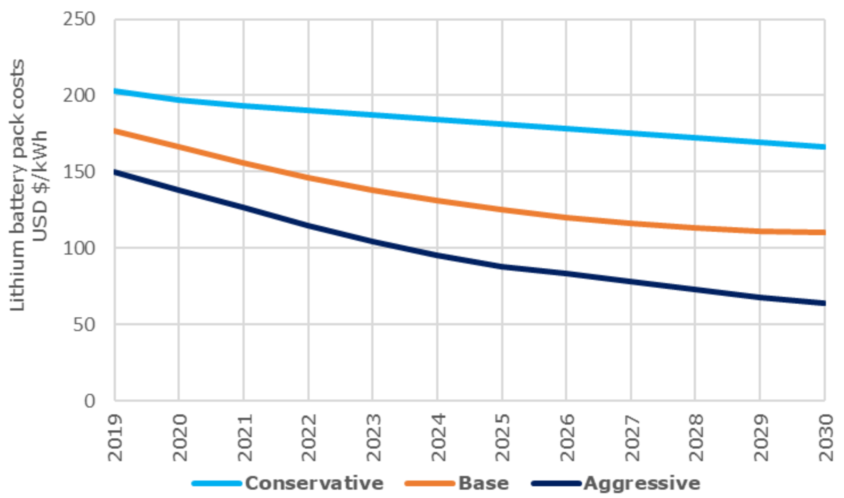

Figure 6 Forecast battery pack costs based on various studies

4.4 Further Work

DNV GL recommends that a cost function be obtained from candidate BESS suppliers which will allow further optimisation studies. In general, a smaller BESS size will result in a higher potential revenue per unit as there will be fewer instances of "unused" BESS capacity. This is shown in Figure 7 for BESS sizes consisting of Tesla Powerpacks.

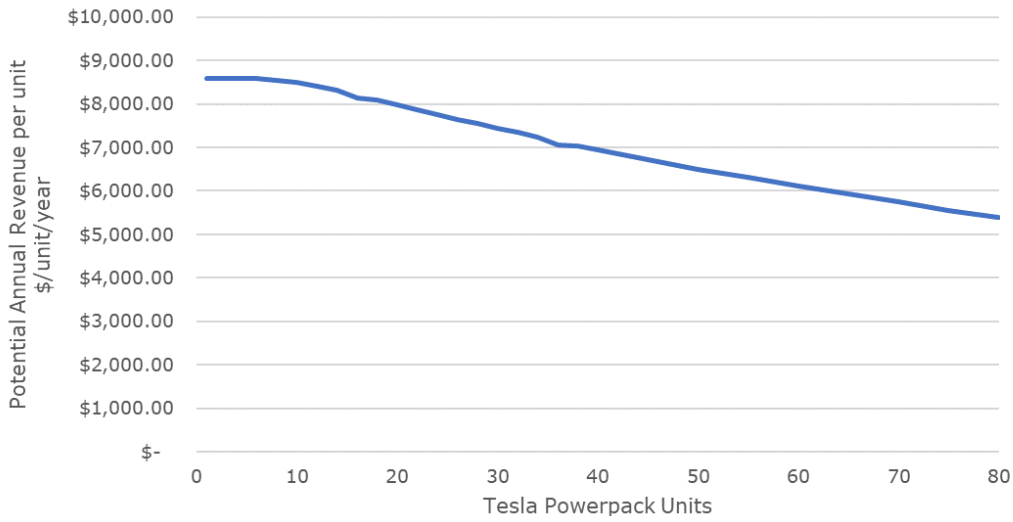

Figure 7 Potential annual revenue per unit for various BESS sizes based on a target price of $30/MWh

Including a function that defines a decreasing cost as the number of units increase will allow the determination of an optimum size with the shortest payback.

Obtaining detailed degradation, temperature dependent charge/discharge and capacity datasheets will also support more accurate sizing studies and modelling across multiple years to estimate a potential lifetime return for a BESS.

The modelling has assumed that the BESS will only charge from excess solar. Further improvement in overall plant revenue may be possible by allowing the BESS to also charge from solar when prices are low. It is recommended to review this with further analysis.

Another modelling assumption has been that the BESS operated under perfect knowledge of upcoming prices. Using forecast prices as an input to the operational logic would yield more realistic estimations of BESS revenue.

5 REFERENCES

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[2] AEMO, "Frequency and Time Error Monitoring – Quarter 1 2020," 2020.

[3] F. Mirzaagha, "Power System Study for Hepburn Wind Farm with Additional Solar Capacity," 2020.

[4] AEMO, "Battery Energy Storage System Requirements for contingency FCAS registration," 2019.

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[6] F. Lambert, "Tesla reveals insane $172,000 Powerpack price and here's why it makes sense," Electrek, 31 03 2020. [Online]. Available: https://electrek.co/2020/03/31/tesla-powerpack-price-commercial-solar/. [Accessed 23 07 2020].

[7] T. Lane, *Email Re:Battery report delay,* 6/08/2020 1:45PM.

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[9] NexTracker [Online], TrueCapture, https://www.nextracker.com/product-services/solar-storage/truecapture/, [Last accessed 20/09/2018].

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APPENDIX A: COMPONENT SPECIFICATIONS

RELECTRIFY

MAKING ENERGY STORAGE AFFORDABLE

Energia-120

Affordable Battery Storage System

- → Reduced cell cost
- → Reduced inverter cost
- → Reduced installation cost

Relectrify creates affordable energy storage by combining high-quality second-life cells from leading electric vehicles using a world-first integrated inverter that optimises every battery cell.

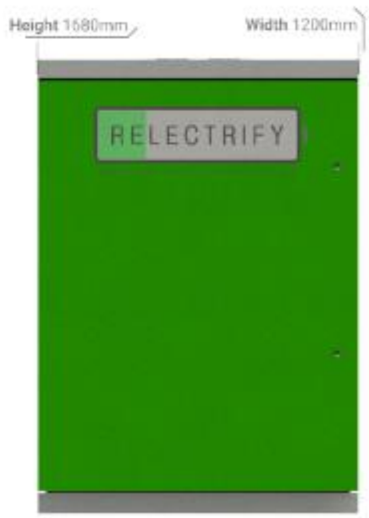
Energia-120 is a 3-phase 120kWh Industrial battery. Its AC-coupled design enables simple and rapid install alongside offering flexible scaling options by combining a multitude of units.

ELECTRICAL SPECIFICATIONS

AC Voltage	400-480V 3-phase
Frequency	50/60Hz
Connection	Grid-tie + Backup
Capacity	120kWh useable
Power	36kVA continuous
AC Efficiency	90% round trip
Scalability	Up to 2.4 MWh
Technical Life	3000 cycles (est.)
Warrantied Life	2000 cycles / 4 yrs
Communication	Modbus TCP/IP; DNP3; Rest API

PHYSICAL SPECIFICATIONS

Dimensions	1560 x 1200 x 1680 mm
Weight	1900kg
Temperature	0°C to 45°C ambient
Humidity	90% (non-condensing)
Location	Outdoor or indoor
Noise Level @ 1m	< 45 dBA at 30°C



CERTIFICATIONS

Battery	IEC 62619
Grid	AS 4777
EMC	IEC 61000-6-1, IEC 61000-6-3

Tesla Powerpack Specifications

Overall System Specs

AC Voltage	380 to 480V, 3 phases
Communications	Modbus TCP/IP; DNP3; Rest API
Power	Up to 130 kW (AC) per Powerpack
Scalable Inverter Power	From 70kVA to 700kVA (at 480V)
Depth of Discharge	100%
Dimensions	**Powerpack Unit** Length: 1,317 mm (50.9 in) Width: 968 mm (38.1 in) Height: 2,187 mm (86.1 in) Weight: 2,199 kg (4,847 lbs) **Powerpack Inverter** Length: 1,044 mm (41.1 in) Width: 1,394 mm (54.9 in) Height: 2,191 mm (86.2 in) Weight (max): 1,120 kg (2,470 lbs)
Energy Capacity	Up to 232 kWh (AC) per Powerpack
Operating Temperature	-30°C to 50°C / -22°F to 122°F
Enclosures	Pods: IP67 Powerpack: IP35/NEMA 3R Inverter: IP66/NEMA 4
System Efficiency (AC) *	88% round-trip (2 hour system) 89.5% round-trip (4 hour system)
Certifications	Nationally accredited certifications to international safety, EMC, utility and environmental legislation.

* Net Energy delivered at 25°C (77°F) ambient temperature including thermal control

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organisations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.