Residential solar PV + battery (Hybrid Energy Service) pilot July 2015 - June 2017

Public report

Acknowledgements

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Report purpose

The purpose of this report is to share the outcomes from Ergon Energy Retail's residential solar photovoltaic (PV) and battery (Hybrid Energy Service) pilot. The outcomes and lessons learnt will enable Ergon Energy Retail to advance the customer and industry outcomes needed to create value from the installation of Battery Energy Storage Systems (BESS).

What's in this report

Section 1 is the executive summary.

Section 2 is the full report that describes the Hybrid Energy Service pilot and its outcomes.

Section 3 includes a series of 'lessons learned' fact sheets.

Feedback

Ergon Energy Retail welcomes further opportunities to share its pilot learnings to help customers and industry. Your feedback on this report can be sent to hybridenergy@ergonenergy.com.au

Important notice

Ergon Energy Queensland has prepared this report for the purpose of fulfilling its knowledge sharing agreement with Australian Renewable Energy Agency (ARENA).

The report has been prepared using information collected from multiple sources throughout the pilot.

While care was taken in preparation of the information in this report, and it is provided in good faith. Ergon Energy makes no warranty as to the accuracy, validity or completeness of the information provided. This report is for concept explanatory purposes only.

Ergon Energy Queensland accepts no responsibility or liability for any loss or damage that may be incurred by any person acting in reliance on this information or assumptions drawn from it.

Explanation of terms used in the report

Acronym	Full Term	Explanation
ARENA	Australian Renewable Energy Agency	
API	Application Programming Interface	A set of computer coding that allows different software applications to communicate with each other to share information or trigger certain actions.
BESS	Battery Energy Storage System	A battery designed to store electricity from generators such as solar PV for use at a later time (in some cases during power outages).
	Demand Response	Demand Response tries to match consumer's demand for power with power generation supply. In the case of this pilot, Demand Response actions included changing the BESS operation (demand) to be responsive to wholesale electricity prices (supply).
DRM	Demand Response Mode	A mode of operation for a Demand Response-enabled device.
DER	Distributed Energy Resources	Decentralised electricity generating resources (e.g. rooftop solar PV) or controllable loads that are connected to the electricity network.
	Demand Management	This is the handling of customer electricity demand at peak times. As a significant amount of investment is put into the electricity network solely to cater to demand during peak times, successful Demand Management at these times may mitigate some of the costs of network upgrades.
EEQ	Ergon Energy Queensland Ltd	Ergon Energy Queensland is the parent company of both Ergon Energy Retail (the retail arm of the company) and Ergon Network (the distribution network – or 'poles and wires') in the regional Queensland area.
HE Service	Hybrid Energy Service	A product that combines solar PV panels with battery storage technology as a bundled service to offer customers' greater choice and control over when, from where, and how much they pay for the energy they use.

HE System	Hybrid Energy System	The hardware and software required to deliver a Hybrid Energy Service.
kW	Kilowatt	A measure of one thousand watts of electrical power.
kWh	Kilowatt hour	A measure of electrical energy equivalent to a power consumption of one thousand watts for one hour. Electricity is sold in kWh increments.
PPA	Power Purchase Agreement	An agreement between two parties where one party generally generates electricity and another buys it. In the context of solar PV systems, a PPA negates the need for the customer to provide upfront capital to have a solar PV system installed. The customer simply buys the generated electricity at a rate (usually) lower than traditional network-supplied electricity.
PV	Photovoltaic	A scientific term describing the production of electric current at the point where two substances are joined and are exposed to light.
RCD	Residual Current Device	A safety device in an electrical circuit (or within equipment) that will break the circuit in order to protect the person using it from electrocution.
SLA	Service Level Agreement	A contract (or part of a contract) that defines the level of service expected from a service provider.
TOU	Time of Use	A pricing plan that has set prices for different and specified blocks of time (i.e. peak, off-peak).
VPP	Virtual Power Plant	A system that integrates and centrally controls several types of Distributed Energy Resources (see above for definition).

1. Executive Summary

In July 2015, Ergon Energy Retail started a pilot to test an innovative residential solar PV and battery storage product as a turnkey Hybrid Energy Service (HE Service).

1.1 How was the pilot initiated?

Ergon Energy Retail saw there was a need for exploration into Hybrid Energy Systems (HE Systems) and Virtual Power Plants (VPPs) and it was clear that these would be part of the energy mix of the future. Ergon Energy Retail wanted to be proactive, and learn and prepare for this future.

1.2 How was the pilot conducted?

The pilot scope included the design, installation, commissioning and operational testing of 33 grid-connected, centrally controllable, solar PV plus Battery Energy Storage Systems (BESS) installed at residential customer premises in Toowoomba (13), Cannonvale (7) and Townsville (13) over a one year period.

The target customers were families living in large modern detached dwellings that had above average electricity consumption (and therefore, larger bills).

The participants had no upfront payment for the service, but paid a participation fee for 12 months instead. Ergon Energy Retail retained ownership of the assets and the right to use them for Demand Response events.

The installed systems included:

1. A 4.9kW solar PV array.
2. A 5kW/12kWh lithium ion BESS.
3. A consumer interface that allowed customers to see the energy flows of the HE System (solar PV, storage, grid supply and export) in real time and historically.
4. An operator interface that allowed Ergon Energy Retail to monitor and operate the HE System remotely as individual units or as an aggregated fleet in real time.

1.3 What was the pilot trying to achieve?

The pilot objectives were to test:

a) **Customer value:** the value of a HE Service to customers (the savings from using the HE Service)

b) **HE Service Business model**: the business model used to offer the HE Service to customers

c) **HE Service Operational model**: the operational model used to deliver the HE Service to customers

d) **HE Systems as a VPP:** the effectiveness of the use of the HE Systems as a VPP.

In addition, the pilot was designed to provide industry with key learnings on the safe and efficient operation of BESS technology.

1.4 What were the results?

Customer value	
Goal	To test whether the HE Service could make electricity more affordable, provide resilience against future price changes, maximise the benefit of 'time of use' tariffs, and create an efficient, low-effort solution for customers that is managed by Ergon Energy Retail.
Results Overview	• The primary reason customers registered for the pilot was the opportunity to save money. • Over the one year pilot, customers did save on their bills through the use of a HE System despite a range of setbacks. However, savings were not guaranteed. The main reason for this was that the HE Systems had 45% downtime rate on average. • Issues with improper installation and equipment failures as well as the complexities of a long supply chain, meant that the HE Service didn't maintain its 'low effort' goals. • The HE System successfully provided backup power during outages (giving the customer reliability).
Learnings	Further work is required to determine how best to increase the certainty and amount customers will save on their bills by having a HE System.

HE Service business model	
Goal	To test the effectiveness of the business model used.
Results Overview	• Having warranties in place was crucial, but contract-based Service Level Agreements (SLAs) were ineffective in assuring the responsiveness of suppliers. • The overall costs to Ergon Energy Retail of system installation and day-to-day running were higher than expected. As the system was running for only 55% of the time, only half the expected customer fees were received (fees were reduced to better reflect system uptime). • The HE Systems were able to reduce peak demand, ensure savings and deliver an aggregated Demand Response, but no revenue was realised from this or from the available Demand Management incentives. • Additional internal resources were required to manage the delivery during the pilot.
Learnings	• Customers require more certainty (less risk) around cost of system versus savings. A Power Purchase Agreement (PPA) model would be more effective for customers (i.e. no upfront capital costs and customers pay only for power used from the system). • Stringent management of the HE Service supply chain is critical to customer experience and the cost effectiveness of the HE Service. • Obtaining value from the HE Service, by retailers and customers, requires continuous monitoring and optimisation. • Widespread deployment of HE Services is likely to be a suitable distributed energy resource to reduce wholesale electricity costs. • Further revision of the HE Service business model is required to improve financial outcomes for all parties involved.

HE Service operational model	
Goal	To test the operational model and technology used to deliver HE Service to customers.
Results Overview	• The HE Systems were able to generate power, charge the batteries for later use and offset customer usage to provide savings. • The HE Systems could be successfully monitored and operated remotely as individual units and as an aggregated fleet in real time. • The HE Service supply chain was the most important factor in managing the operational model – installation and hardware problems contributed to 45% downtime (on average). • Data accuracy and quality was sub-optimal due to HE System constraints (however, the data gathered sufficed to provide explanations about the outcomes of the pilot).
Learnings	• The key lessons were that clear HE System performance criteria and rigorous contract management were required to deliver the planned business and customer outcomes.

HE Systems as a VPP	
Goal	To test the use of the multiple HE Systems as a VPP.
Results Overview	• The HE System's potential value was reduced by limitations related to the Ergon Energy Network connection standard in place at the time of the pilot, as well as data inaccuracy in the HE Systems. • As Demand Response events were generally between 4pm – 8pm, the solar PV was still generating and the batteries were relatively full at this time. Therefore impact on customer savings was negligible, making this aspect of Demand Response highly successful.
Learnings	• The Demand Response initiation was processed manually during the pilot, but this caused issues aligning Demand Response events with peaks in wholesale market prices. Any future aggregated HE System should be integrated with trading (or VPP) platforms, so power can be discharged automatically when needed. • As there are many factors impacting individual HE Systems at any given time, a successful VPP model would require deployment at a larger scale to provide the diversity needed for them to be valued as a reliable resource.

2. Full Report

2.1 Introduction

In July 2015, Ergon Energy Retail launched a pilot to test an innovative residential solar Photo Voltaic (solar PV) and battery storage product as a turnkey Hybrid Energy Service (HE Service).

The aim was to test the HE Service in a live customer context to ascertain whether there was value for customers and networks and whether Ergon Energy Retail could derive business and strategic benefits from the large scale deployment of solar PV plus storage systems.

At the time the pilot began, the cost of solar PV systems was reducing and Battery Energy Storage System (BESS) were entering the market as a high-profile emerging technology. There were widespread industry expectations that the uptake of household storage systems would increase rapidly, with economies of scale making batteries affordable for customers. In addition, Ergon Energy Retail's market research found customers wanted more control and certainty over their bills[1] and this theme continues today[2].

New business models were also emerging that allow retailers and other energy services companies to use their bulk buying power to offer customers no or low upfront costs solutions so customers could access the benefits of HE Services.

Ergon Energy Retail hypothesised that the likelihood of customer interest and potential uptake of BESS products was high given the prevalence of solar PV ownership within our customer base and regional Queensland's record of extreme weather and its associated power outages.

2.2 Pilot objectives

The five pilot objectives were to:

1. Test the value of a HE Service for customers
2. Test the effectiveness of business model used to offer the HE Service to customers and the parameters required for a commercial proposition
3. Test the operational model and technology used to deliver HE Service to customers
4. Test the use of the Hybrid Energy System (HE System) as a Virtual Power Plan (VPP)
5. Provide industry key learnings on the safe and efficient operation of BESS technology.

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[1] Customer Experience Tracking Report, Residential and Business, Quarter 1: 2015.
[2] Customer Experience Tracking Residential and SME, May 2017.

2.3 Pilot scope and pilot design

Participant profile

The pilot scope included the design, installation, commissioning and operational testing of 33 grid-connected, centrally controllable, solar PV plus BESS systems installed at residential customer premises in Toowoomba (13), Cannonvale (7) and Townsville (13) over a one year period. The target customers were families living in large modern detached dwellings that had above average electricity consumption (and therefore, larger bills).

Customer contract

The HE Service customer contract required no upfront payment for assets or installation, with customers agreeing to pay a monthly participation fee for one year with the option to extend for a further nine years. Ergon Energy Retail retained ownership of the system and the contract included an allowance for Ergon Energy Retail to use the HE System for Demand Response events.

HE System description

The HE System comprised of four components:

1. A 4.9kW solar PV array
2. A 5kW/12kWh lithium ion BESS
3. A consumer interface that allowed customers to see the energy flows of the HE System (solar PV, storage, grid supply and export) in real time and historically
4. An operator interface that allows Ergon Energy Retail to monitor and operate the HE System remotely as individual units or as an aggregated fleet in real time.

Pilot elements and responsibilities

Step	Description	Responsibility
1	Customer acquisition and support	Ergon Energy Retail
2	Network connection applications	Ergon Energy Retail
3	Technical inspection and system design	Principal contractor / subcontractors
4	Installation and commissioning	Principal contractor / subcontractors
5	Customer web portal and central fleet management control system	Principal contractor / subcontractors
6	Corrective and preventive maintenance	Principal contractor / subcontractors
7	Pilot testing, optimisation of the system for the customer and reporting	Ergon Energy Retail and Principal contractor / subcontractors

2.4 Outcomes

The pilot addressed all objectives and the outcomes below are the key results and learnings on the safe and efficient operation of BESS technology.

Objective 1: Customer value proposition	
Goal	To test the value of a HE Service for customers. The expected value of the service to customers was: • Greater control and certainty over electricity price through fixing the cost of a proportion of the electricity use and reducing their exposure to future price changes • Ability to enable set and forget programming to maximise benefits from Time of Use (TOU) tariffs • Electricity supply during power outages • Ability to maximise their use of generation from their solar PV • A low effort solution with Ergon Energy Retail optimising the HE System savings • Peace of mind with Ergon Energy Retail managing installation and on-going operation and maintenance.
Challenges	Major challenges faced were: • Providing value for money • Installation issues • HE System failures and limitations • Complex and lengthy supply chain (see Objective 3 for more details).
Results	In a survey of 25 of the 33 participating customers, results showed the primary reason customers registered for the pilot was the opportunity to save money. The pilot showed that there a number of factors that impact on the ability for customers to gain value from the HE Service, for example their usage behaviour over time. *See what worked and what didn't on the opposite page.*
Learnings	• There are a number of factors that must be taken into consideration in order to increase the certainty that customers can save on their bills by having a HE Service. • Further work is required to refine how backup power should be configured and controlled to optimise the value to customers. • Further work is required before the benefits of tariff optimisation using BESS can be demonstrated.

Results for Objective 1: Customer value proposition

What worked

- A level of savings was achieved despite the setbacks (several hundred dollars per customer, per annum, on average)
- In response to 45% HE System downtime, Ergon Retail adjusted the participation fees to ensure customers were better off financially for participating in the pilot.
- The HE Systems were able to provide backup power when required for short and long term power outages. The majority of occasions where backup power was required were less than one hour with an average of 0.6kWh per outage. The HE Systems in Cannonvale provided seven days backup power during the network outage caused by Tropical Cyclone Debbie in April 2017. A *case study* of the customer experience during this event is on the next page.

What didn't

- Due to the Objective 1 challenges, the systems were only available to participants for 55% of the time (on average).
- Saving money is not guaranteed for customers.
- The ability for customers to take advantage of new cost-reflective tariffs (that reward customers for managing their load profiles to reduce network costs) was hampered by the limited availability of the HE Systems.
- The HE Service was not a 'set and forget' customer experience, e.g. when certain equipment faults occurred, unrelated to network outages, HE Systems had to be manually put into bypass mode. In these instances, a HE System support was required seven days a week from all parties (Ergon Energy Retail, contractors and customers). Typically the manual bypass had to be achieved within 24 hours of the fault otherwise the customer lost power to their backup (essential load) circuits.

CASE STUDY: Customer experience during Tropical Cyclone (TC) Debbie

In March 2017, Cannonvale was impacted by TC Debbie and the community lost power for seven days. Four of seven customers had access to backup supply from the HE System. The cyclone directly damaged three HE Systems; one required a solar PV panel to be replaced, one customer's battery could not be charged and a third customer's roof was damaged, rendering it unsafe to use the solar PV system.

Following expert input from the manufacturers, Ergon Energy Retail undertook a number of actions to ensure the safety of customers. Prior to the cyclone hitting, customers were advised their systems were being charged so they could supply the essential circuits if there was a network power outage. Customers were advised not to interfere with their HE systems before during or after the event.

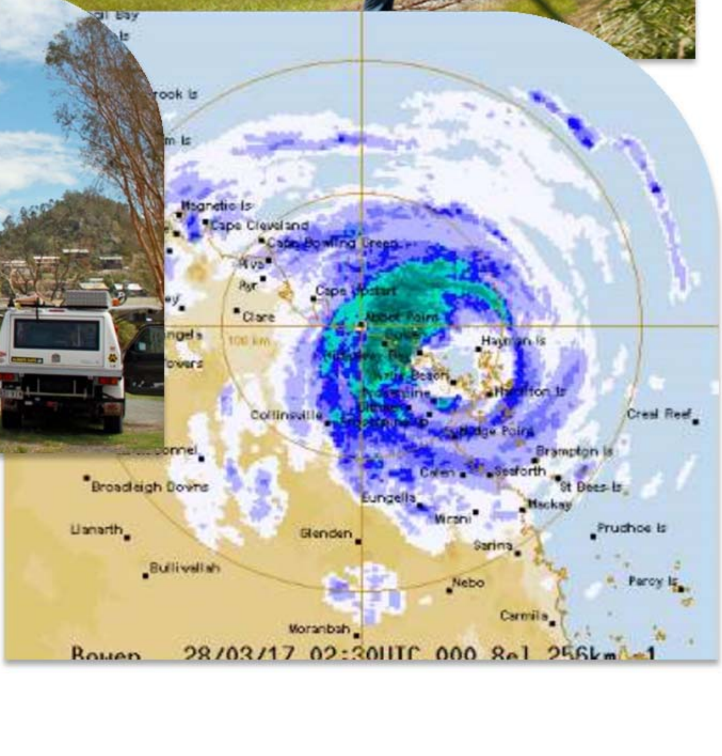
Separately, Ergon Energy Network issued notices directing customers to switch off solar PV and battery systems in areas where temporary generation was deployed. This was to avoid reverse power flows in areas where the network establishes temporary generation resources during major outages.

After the cyclone, all customers with operating systems strongly indicated they wanted to utilise their backup power. Ergon Energy Retail arranged for a qualified electrical contractor to attend each premises to perform a safety inspection on their HE system and, where they were operational, to isolate their system from the network so that they could continue to use backup power as planned. This action whilst adding overall cost ensured customer safety and avoided issues associated with reverse power flows into the network. It also allowed the customers to continue to use their HE systems during the entire power outage.

The apparent inconsistencies in procedures during Cyclone Debbie highlight the gaps in standard procedures for BESS systems during extended outages and the lack of available technical solutions to ensure customers can access backup power during network outages whilst ensuring their safety and maintaining network stability.

"I'm using the solar from hybrid to power other half of house. Not happy with recommendation to leave in Bypass until advised otherwise. If I can't use it in a situation like this then we might as well remove it as this is really the only time it's needed" – pilot participant

"I'm worried that by turning it off our power will not be supplied. As you are aware we have been hit by a cyclone and the power is running our fridge. We have four small children and I'm keen to keep it going" – pilot participant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Objective 2: HE Service business model	
Goal	Test the effectiveness of the business model used to offer the HE Service to customers.
Challenges	• The HE Service can only be priced based on what customers would pay to save money with a slight premium for access to back up power. • The fixed-fee pricing model created unacceptable risks to customers due to the uncertainty in predicting how much they would save. • The Ergon Energy Network Demand Management incentive potentially applicable to the Cannonvale installations was not a source of revenue. Modelling showed the despatching of BESS capacity according to an Ergon Energy Network provided schedule (2kW for four hours from 4pm on summer weekdays) in return for a financial incentive, would have left some customers worse-off. Therefore the Network Demand Management schedule was not implemented. • Internal resource requirements were substantially higher than expected due to managing customer issues created by delays in installation and fault rectification.
Results	The HE Service business model tested was not effective. *See what worked and what didn't on the opposite page.*
Learnings	• The availability and efficiency of the systems will need to increase to a minimum of 95% to ensure a return on investment. • The HE Service could be more effectively priced as a PPA where customers pay for energy used from the system. Customers would be no worse off from this model and Ergon Energy Retail would be able to call on the systems for Demand Response purposes and retain the value of the exported energy. • Management of the HE Service supply chain is critical to customer experience and cost effectiveness. From experience during the pilot, the following key success factors were identified: o Improved specification of the system requirements to remove identified hardware deficiencies o Comprehensive training of subcontractors on installation procedures o Effective and timely fault management o Timely and transparent communication with customers. • Obtaining value from HE Services requires continuous monitoring and optimising of multiple variables including: o Sizing of the solar PV and BESS to suit customers' load requirements o Programming BESS operation to optimise usage of solar PV generation and BESS capacity o Retail tariffs available to residential customers e.g. TOU o Home energy management including determining the

	discretionary loads that can be shifted to maximise HE System usage o Responding to changes in energy usage behaviours over time o Managing the availability of storage for severe weather events. • Widespread deployment of HE Systems could be an important component of a VPP to reduce wholesale electricity costs.

Results for Objective 2: HE Service business model

What worked

- Having warranties in place shielded Ergon Energy Retail from incurring unexpected costs.
- The HE Systems were able to perform aggregated Demand Response with appropriate (sub-minute) response times in most cases.

What didn't

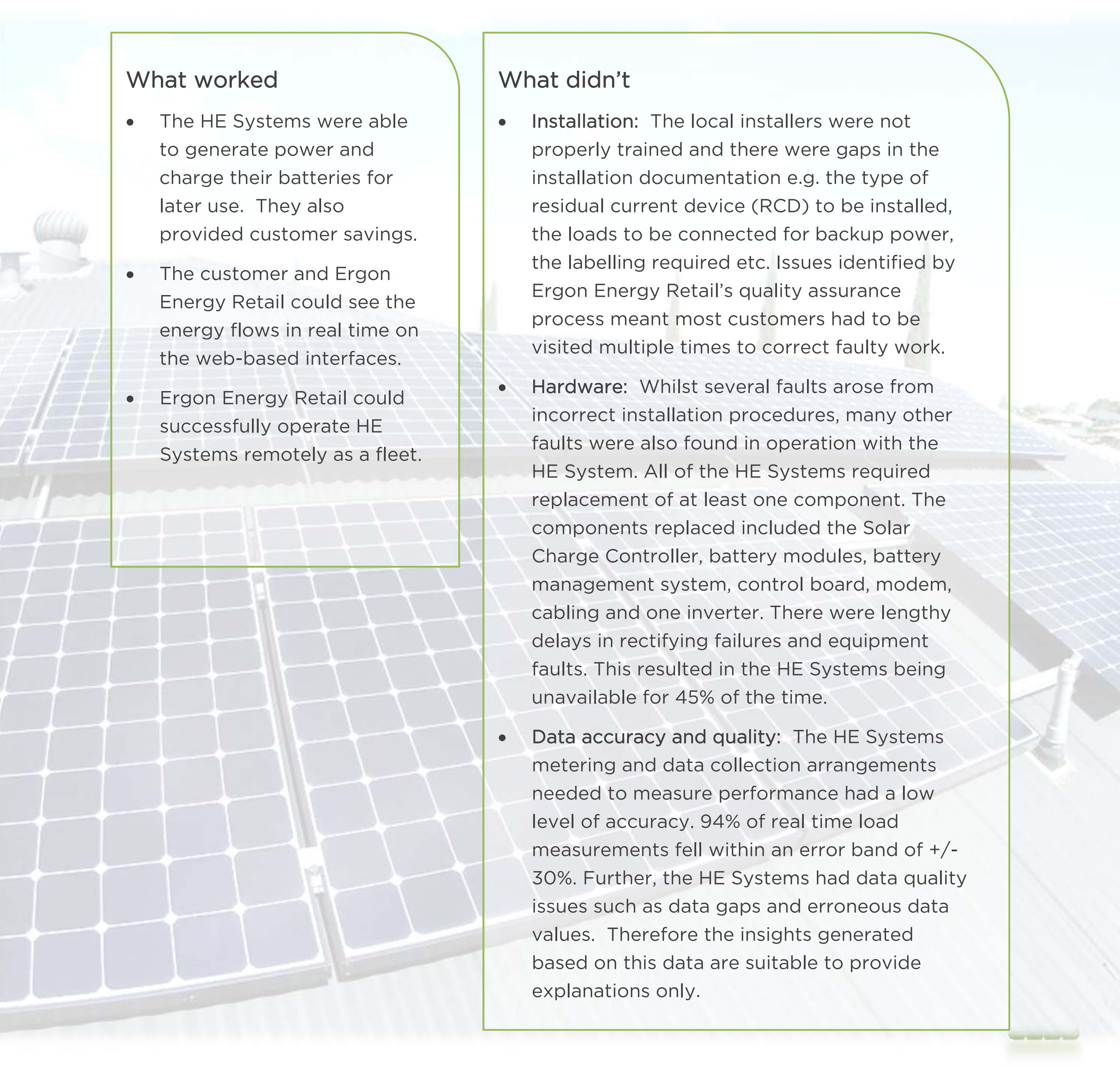
- Actual costs were higher than budgeted. Increases in installation costs to suit the characteristics of some sites meant installation costs at 45% of sites exceeded the planned budget.
- Two customers required compensation for food spoilage when the HE System ceased to supply power to their essential circuits (the circuits that are fed by the HE System in the case of a network outage).
- The limited availability of HE Systems limited customer savings which reduced the amount of monthly fees that could be recovered by approximately 50%.
- SLAs (and associated defects/liability penalties) with third-party providers were ineffective in driving better outcomes.
- There was increased pressure on internal resources to manage service delivery.

Objective 3: HE Service operational model	
Goal	Test the operational model and technology used to deliver HE Services to customers.
Challenges	• The pilot supply chain reduced Ergon Energy Retail's ability to ensure customers received a high performing system and have a positive experience. • At the time of the pilot, all Ergon Energy Network connection applications required a technical assessment under Ergon Energy Network's standards for inverters with a capacity rating of 5kVA or greater. This assessment resulted in: 1. 31 of the 33 units were able to be connected as proposed 2. Two units were able to connect with a partial export limit of 3.5kVA (programmed into the inverter) 3. Activation of the inverters required the power quality mode 'Fixed Power Factor 0.9 lagging (inductive)' • Items 2 and 3 effectively reduced the HE Service value to both customers (savings) and Ergon Energy Retail (as a VPP/Demand Response asset).
Results	The success of the HE Service operational model is heavily dependent on the management of the HE Service supply chain. The turnkey delivery model consisted of several stakeholders over a wide geographical range. At times this impacted on the quality and efficiency of installation and fault rectification. The outcomes of these issues were to limit the working availability of the systems, additional costs, multiple customer visits, and an unsatisfactory customer experience> managing the impacts of delays and revisits required increased Ergon Energy Retail resource effort to manage the pilot. *See what worked and what didn't on the opposite page.*
Learnings	• The key learning for Ergon Energy Retail was that clear HE System performance criteria and rigorous contract management is required to effectively manage outcomes. • The customer suitability, technical assessment and system design process could be improved to ensure that there are no gaps in information needed from site including: o Identification of the design and environmental considerations e.g. the customer agreed battery location; o Identification of all works required to bring a site up to standard for an install e.g. electrical switchboard work and any structural work for locating the solar PV or BESS unit; and o Identification of the essential circuits to feed essential household loads (lights, refrigerators etc.) to be supplied with backup power. An understanding of both in their steady state and their surge requirements, the higher instantaneous current drawn by an electrical device when first turned on, for correct sizing of the

circuit breakers.

- The on-going Ergon Energy Retail costs (software licences, operation and maintenance fees) were high relative to the HE Service monthly fee being recovered from customers. Together with the capital cost of the system, these on-going costs make it difficult for the HE Service to achieve Ergon Energy Retail's required rate of return.
- While the data was imperfect due to the issues listed above, it is sufficient to provide insight for concept explanation and lessons learned.

Results for Objective 3: HE Service operational model



What worked

- The HE Systems were able to generate power and charge their batteries for later use. They also provided customer savings.
- The customer and Ergon Energy Retail could see the energy flows in real time on the web-based interfaces.
- Ergon Energy Retail could successfully operate HE Systems remotely as a fleet.

What didn't

- Installation: The local installers were not properly trained and there were gaps in the installation documentation e.g. the type of residual current device (RCD) to be installed, the loads to be connected for backup power, the labelling required etc. Issues identified by Ergon Energy Retail's quality assurance process meant most customers had to be visited multiple times to correct faulty work.
- Hardware: Whilst several faults arose from incorrect installation procedures, many other faults were also found in operation with the HE System. All of the HE Systems required replacement of at least one component. The components replaced included the Solar Charge Controller, battery modules, battery management system, control board, modem, cabling and one inverter. There were lengthy delays in rectifying failures and equipment faults. This resulted in the HE Systems being unavailable for 45% of the time.
- Data accuracy and quality: The HE Systems metering and data collection arrangements needed to measure performance had a low level of accuracy. 94% of real time load measurements fell within an error band of +/- 30%. Further, the HE Systems had data quality issues such as data gaps and erroneous data values. Therefore the insights generated based on this data are suitable to provide explanations only.

Objective 4: Effectiveness of HE Systems as a VPP	
Goal	Test the use of the HE Systems as a VPP.
Challenges	Defining the value of HE Systems to the business as a VPP and Demand Response tool.
Results	The HE Systems' potential value as a VPP was reduced by limitations to do with the Ergon Energy Network connection standard in place at the time of the pilot, as well as the meter inaccuracy in the HE Systems. *See what worked and what didn't on the opposite page.*
Learnings	• Demand Response processes were manual for the pilot. Forecast wholesale market price peaks did not always correspond to the manually scheduled Demand Response event. In order to dispatch the HE System to match peak events, aggregated HE System controls should be integrated with trading (or VPP) platforms, via the available Application Programming Interface (APIs), to be discharged when threshold price levels are reached. • HE System reliability also impacted their effectiveness for Demand Response. HE Systems would need to be deployed at scale to provide diversity and for value to be derived from load reduction and the export of electricity (and warrant Ergon Energy Retail investing in the integration via APIs).

Results for Objective 4: Effectiveness of HE Systems as a VPP

What worked

- No pre-event program control was needed to ensure the BESS were sufficiently pre-charged and available for Demand Response requirements. Most of the requested events were during the peak period (4-8 pm on weekdays) or early evening and at this time and due to the daily charge cycle, the BESS is relatively full (charged) at this time.
- The potential downward impact of Demand Response events on customer savings was negligible.

What didn't

- Ergon Energy Network's connection standard required some systems to be de-rated (connected at a lower capacity and export limited) which reduced their potential value.
- The inaccuracies in real time power measurement required all systems to be de-rated to account for the error band which further reduced their potential value.

2.5 Conclusion

The pilot has identified a number of key success factors that provide a roadmap for refining HE Services as a commercially viable customer offer in future. Key factors include:

- Price: the combined price of solar PV and BESS must drop below $10,000.
- Reliability: the reliability of HE Systems must increase to around 95% availability.
- Efficiency: system losses must reduce below 5%.
- Standards: the industry should adopt consistent installation standards for BESS and their safe operation during network outages.
- Supply chain: the industry should facilitate comprehensive training on all aspects of BESS installation.
- Configuration: HE systems need to be able to supply all major loads in the premises which may necessitate some reconfiguring at the switchboard.
- Functionality: the software and hardware design has to be 'set and forget' for the customer at low or no ongoing cost.

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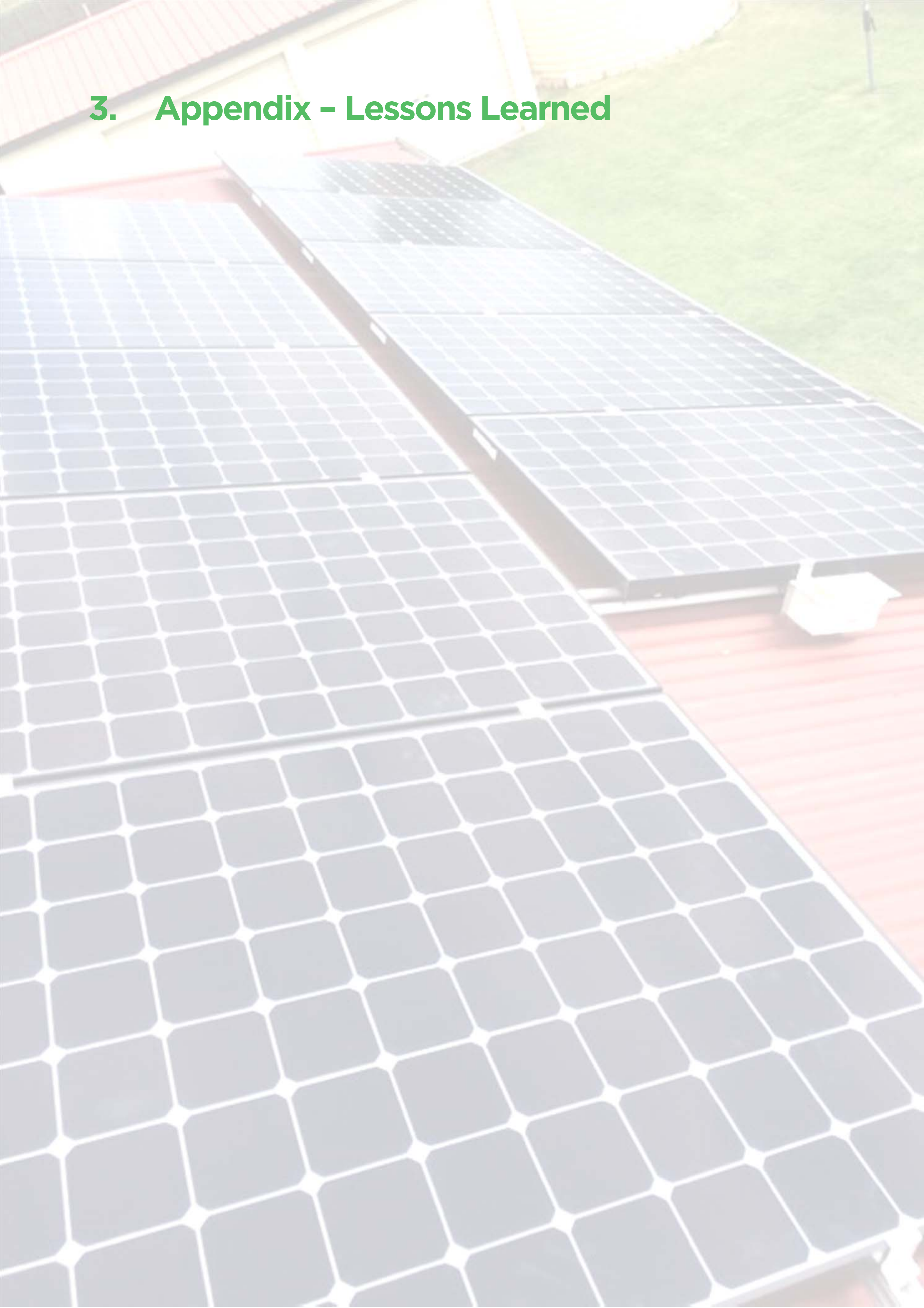
BESS controlled as a VPP can provide real time Demand Response. The ability for customers, retailers and networks to gain additional value from having BESS available for Demand Response is expected to influence how BESS is offered in the future.

The evolution of the market conditions and regulations will continue to affect the value proposition of BESS for all the parties involved and will influence the design and delivery of a product such as an HE Service.

3. Appendix – Lessons Learned



3.1 HE Systems must be flexible to meet customers' needs

Knowledge Category:	Financial
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

The standard HE System design, a 4.9kW solar PV and 5kW/12kWh BESS, did not suit all targeted customers. For example, many of our customers with high consumption had either a three phase supply or their large loads such as air conditioners and hot water systems were on off-peak tariffs, reducing the amount of grid consumption they could offset from using the HE System.

The standard HE System design, a 4.9kW solar PV and 5kW/12kWh BESS, did not suit all participating customers during operation over the pilot period. For example, customers changed their usage by going on extended holidays, renting or selling their property, all of which impacted the suitability of the standard HE System design.

Implications for future projects

The product offer will need to cater for different Network supply arrangements, the connection of all large loads, as well as customers' lifestyle changes, such as a change in occupancy.

It is important to have a clear understanding of customer's consumption as well as their load profile. The introduction of digital meters under Power of Choice (PoC)[3] will provide valuable information to determine the customer suitability of a HE Service.

Customers were conscious of the aesthetics of the solar PV and BESS. The look and placement of the HE Systems was a barrier for some customers. In future, customer preferences will need to be more readily accommodated in the product offer and in the HE System design.

[3] PoC, which came into effect 1 December 2017, is a suite of reforms and changes to the Australian electricity regulatory framework.

3.2 Network connection standards can impact the customer and business value of a HE System

Knowledge Category:	Financial
Knowledge Type:	Network connections
Technology Type:	Storage

Key learning s

Ergon Energy Network's connection standard required some systems to be de-rated (connected at a lower capacity and export limited). The main impacts were a reduction in the solar PV generation, as the system could not turn down the solar PV output, as well as a reduction in the available capacity for Demand Response purposes.

Implications for future projects

The previous Network connection standard - applicable at the time - has now been changed. The new Queensland Connection Standard for Micro Embedded Generating (EG) Units 0 to 30kVA will allow automatic approval by Ergon Energy Network of HE System of the same size and as a result the value propositions would no longer be potentially impacted by the network connection process.

Standards will continue to be updated over time and this has the potential to effect the HE System value propositions. In addition, the Ergon Energy Network connection application processes can impact on customer experience and needs to be considered in product delivery to ensure the best customer experience is achieved.

3.3 The effectiveness of the HE System was reduced by inaccuracies in real time power measurement

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

While the HE System functional specification required that the HE System's internal metering have accuracy of no less than +/- 2% for site load measurements and +/- 5% for other measurements, such as flows in and out of the inverter, the latter was only achieved at 6kW, the full rated capacity of the inverter. Further investigation found:

- Incorrect placement and installation of CTs during installation reduced the accuracy of the site load measurements
- The error for inverter measurements was +/- 300W at any power level, resulting in error levels at low power levels higher than +/- 5%. 94% of all individual real time load measurements fell within an error band of +/-30%.

The implications of this level of inaccuracy are listed below:

- The inverters had to be de-rated below the error band to comply with their Network connection agreement, further reducing their value as a Demand Response resource;
- The BESS control program was operating with inaccurate inverter values and this reduced its efficiency in offsetting load for customer savings
- Inaccuracies in real time measurement made it problematic for Ergon Energy Retail and customers to monitor, reconcile and make HE System optimisation decisions based what is happening in real time.

Implications for future projects

Ergon Energy Retail proposes that HE Systems are metered using National Measurement Institute (NMI) approved revenue grade (digital) metering[4] on all electricity flows that affect customer value/savings. This would, improve the performance of the HE System and to leverage the existing Ergon Energy Retail digital meter capability such as information security, data transfer, billing, analysis, reporting and presentation. Metering for the HE System should consider integrating with the existing premises digital metering assets to avoid duplication and cost.

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[4] The NMI approved metering would not to be settled in the NEM and therefore it is not essential for it to also be approved for use in the NEM.

3.4 The ability to evaluate the benefits of the HE Service was impacted by data quality

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

In addition to the level of metering error (outlined in 3.3) there were also data quality issues, such as data gaps, erroneous data etc., that stemmed from the HE System. As a result, the effectiveness of the HE Systems (i.e. how much customers could potentially save on their bills and how much capacity they provided during Demand Response events) could not be verified with high certainty.

A single source of data truth is important from real time monitoring in the consumer interface and operator interface through to historical billing, analysis and reporting of the various HE Service value propositions.

Implications for future projects

In addition to the recommendation for the HE System to use more accurate, revenue grade metering, the data collection from HE System should be supported with a comprehensive archiving database that includes data from multiple internal sources (i.e. meter data, billing data) and external sources (i.e. HE System recorded metrics such as state of charge, temperature etc.). This database would enable analysis and reporting to be performed in a single environment. It is also recommended that a data model and any performance reports are developed prior to deploying these types of HE Systems.

3.5 Self-learning HE System control increased customer savings

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

The HE Systems were initially programmed to operate according to rulesets. These were found to be sub-optimal as they did not adequately account for the continual changes in customers' usage patterns. During the pilot, a self-learning algorithm was implemented to control the operation of the HE System. This enabled the BESS system to respond more dynamically to customer's changes in behaviour and marginally increase savings for customers.

Implications for future projects

This type of self-adjusting, responsive algorithm would be required if HE Systems were to be deployed at scale to optimise customers usage of the system by self-correcting for changing energy usage behaviours.

3.6 System design, system reliability and supply chain efficiency are the key to achieving benefits from HE Service

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

Factors contributing to loss of performance

There were a number of hardware and software issues encountered during the pilot that ultimately affected the amount of savings realised by customers. The average customer savings realised was 40% of the maximum potential savings from the HE System. Nevertheless, every customer was able to save money on their bill from the use of the HE System. Further analysis identified the main factors that contributed to the sub-optimal performance and this is shown in Figure 1.

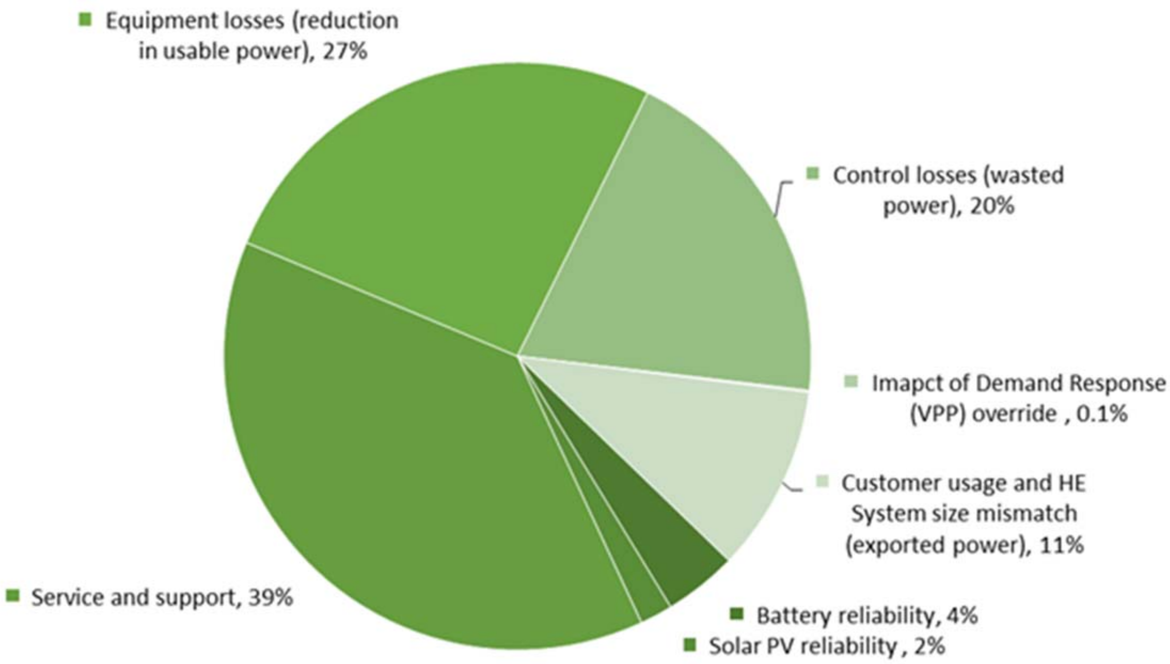

Figure 1: Factors in relative terms that contributed to the HE Service sub-optimal performance.

The loss factors included:

- Battery reliability (4%): This is the contribution of the BESS equipment failures. The main failures were associated with the Solar Charge Controller, battery modules, battery management system, control board, modem, cabling and breakers tripping due to the software control of the inverter.
- Solar PV reliability (2%): This is the contribution of solar PV equipment failures. These were limited to one inverter and a faulty DC isolator.
- Service and support (39%): This contribution is associated with delays to restoring HE Systems to full working condition. Whilst the equipment failure rate of the Solar PV and the BESS was higher than expected, it was the delay in responding to these failures by contractors that had the greatest effect on the customer value for money.
- Equipment energy losses (27%): This is the contribution of losses of energy in the inverter, stand-by and battery including 'parasitic' losses. These losses include energy conversions and heat losses, with the combined net result being a reduction in usable power to offset the customers load and deliver savings. These losses were higher than expected.
- Control Losses (20%): These losses are associated with efficiency of the inverter control i.e. the ramp up/down speeds, buffers etc. Included are losses associated with high voltage battery defence mode, where the battery discharges when near fully charged to protect the battery. The combined net result of these losses is wasted usable power for customer savings. These losses are also a function of inaccurate real time measurement of the electricity flows, and therefore, the sub-optimal control of the HE System (3.3 above). The control losses were higher than expected.
- Impact of a Demand Response override (0.1%): This minor loss in customer savings is a normal/anticipated result when the control program is overridden by a Demand Response event.
- Customer usage and HE System size mismatch (exported power) (11%): This contribution is where the HE System was over-sized compared to a customer's usage profile and/or the customers' behaviour changed during the pilot i.e. someone moved out or was away for extended periods. As a result, the output of the solar PV system was in excess of the customer's usage and what the battery could store, and thus was then exported to the grid. Due to changes in customer behaviour, the export levels were higher than anticipated.

Site visits

Figure 2 shows the reasons for resource-intensive customer site visits post commissioning. This chart shows that 50% of site visits would have been unnecessary if there was better documentation, training and end to end processes put in place by the contractors (who were also learning about this technology during the course of the pilot). There is an opportunity for a quick win for future projects to improve the reliability of the HE System and minimise the need for a number of site visits through the above actions.

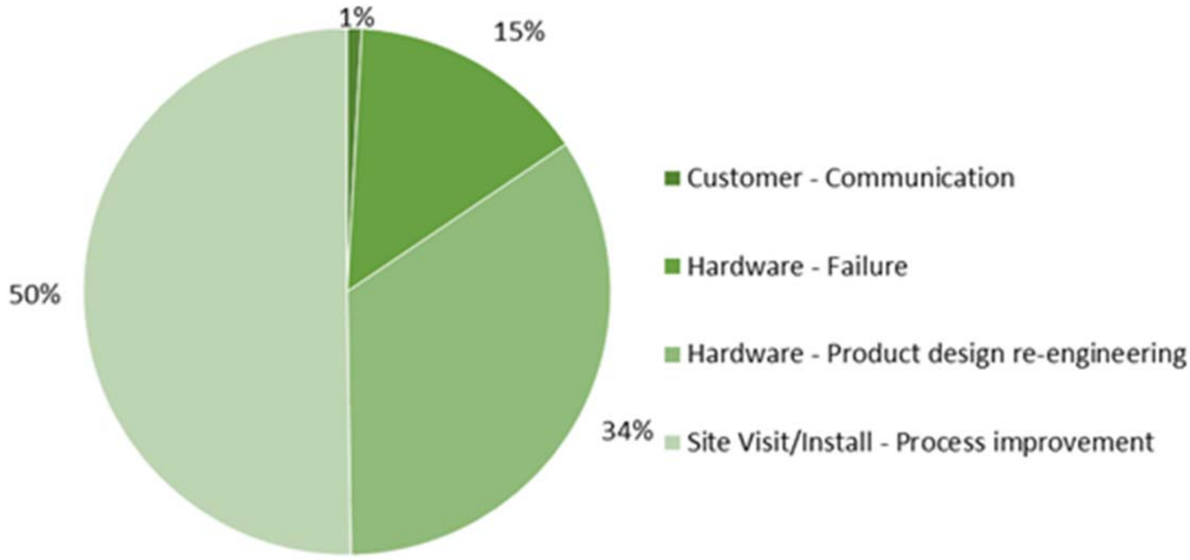

Figure 2: Reasons for post-commissioning site visits

Reasons for site visits included:

- Customer – Communication (1%): The customers had to manually put the system in bypass mode for certain system failures to ensure uninterrupted electricity supply. Site visits by installers had to be arranged where a customer could not be contacted. If this requirement is not removed via future product design, it could be removed through better communication and training than was provided during the pilot on why, how, when and the response timeframes needed to put the system in bypass.
- Hardware – Failure (15%): The failure of components under warranty could be minimised through more diligent selection of all componentry. The system was only as strong as its weakest link and failures can occur from a simple cable connection fault to an inverter or battery failure. All failures had the same impact on the customers' ability to save money.
- Hardware – Product design re-engineering (34%): Site visits to rectify product failures could be substantially reduced through better product design, engineering and quality assurance.
- Site Visit/Install – Process improvement (50%): Site visits to rectify some design, installation and commissioning issues.

Implications for future projects

The end to end process for designing, installing and operating the HE System will need to be redesigned in future to incorporate the latest installer training accreditation requirements, industry standards (e.g. safety) as well as the pilot lessons learned.

The HE System capital cost could be improved in future by aligning the products' functional specification to the length of contract a customer is prepared are enter into, with the aim to avoid having to replace components mid-contract or paying for functionality that is not required. Suggestions include:

- Batteries have a minimum cycle life of 4,000 cycles daily with 80% depth of discharge and a warranted output for 10 years
- HE System electronic components need to be certified at high temperatures to extend their life in line with the batteries.

The HE System viability could also be improved through improved hardware, for example:

- Use of smaller, lighter modular components that require no more installer resource on site than a standard solar PV installation
- Smaller (capacity) modular batteries where additional capacity can be added over time if customer energy use behaviour changes
- Mounting components in a racking type system on walls to eliminate the need for costly concrete bases and to allow for easy replacement of parts
- Standard pre-wired, plug and play connections would enable quicker installation, commissioning and maintenance
- Designed to remain operational in part in the event of single component failures (excluding the inverter). This would enable the system to provide at least partial customer benefit even when operating in a reduced failsafe mode. For example individual battery modules should be able to be isolated if there is a fault, so that the HE System is still operational but just at a reduced battery capacity
- Designed with an automatic failsafe mode to reduce or eliminate the need for customers to manually bypass the system during certain system failures
- Designed with an inverter appropriate to the application, for example:
    - Smaller capacity inverters with a flatter efficiency curve
    - Inverters where expensive type B RCDs are not needed
    - Inverters with faster ramping response for better control
    - Inverters with integrated battery and discretionary load control
- Reducing equipment (energy) losses during the operation of the HE System. Examples of how this could be achieved include enhanced management of heat sources to reduce the fan use, such as not having the Solar Charge Controller located in the same enclosure as the battery.

The HE System software control solution should use revenue-grade digital metering on all electricity flows associated with the customer value proposition and include a self-reboot so that a site visit is not required. The HE System viability could also be improved through an improved software solution, for example:

- Dynamic use of backup power reserved capacities via weather forecasting or other method to provide more customer savings
- Have the ability to control large discretionary loads as part of a Home Energy Management System
- Meet the requirements of a Demand Response Controller as per AS/NZS 4755, with the ability to apply Demand Response Modes to HE Systems as a fleet
- Be efficient in retrieving and hosting data including optimising what, when and how data is collected through to where the system is hosted considering Privacy and Information Security laws
- Produce NEM12 meter data files on the customer value proposition
- Have no or very low ongoing costs.

3.7 There a number of requirements for HE Systems to be safely used for longer term backup power

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

In March 2017 Cannonvale was hit by Tropical Cyclone (TC) Debbie. In the aftermath, the network in some parts of Cannonvale was inoperable for over a week. Customers wanted to use their HE Systems to have power during the outage, but this conflicted with Network safety advice that required that grid-connected BESS systems be turned off where temporary generation was being deployed, to ensure the safety of crews working on repairing the lines.

Key learnings

An end to end process for Ergon Energy Retail-owned HE Systems in severe weather needs to be developed, including processes and methods to:

- Identify which customers are likely to be affected by the severe weather and when.
- Ensure HE Systems are pre-charged
- Ensure consistent messaging including pre-prepared customer communications and installer instructions
- Ensure prompt post event responses by having qualified technicians available to visit site post the event.

Implications for future projects

The process pre- and post- a severe weather event has a cost and performance impact on HE Services and as such needs to be reflected in the customer value proposition as well as the any business and operating model.

Current inverter standards may present an opportunity to identify a Demand Response Mode (DRM) that could be remotely applied to HE Systems that would be acceptable to Ergon Energy Network. The DRM could enable them to operate (after an inspection) without being physically isolated from the network when temporary generation is deployed. This would negate the need for further site visits to return the system to normal operation.

3.8 Battery fleets could provide effective Demand Response if deployed at scale

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage

Key learnings

Most of the wholesale requested Demand Response events were during the peak period (4-8 pm on weekdays) or evening and at this time and due to the daily charge cycle, the BESS is relatively full (charged). However the forecast wholesale market price peaks did not always correspond to the manually scheduled Demand Response event.

Implications for future projects

In order to dispatch the HE Systems to match peak events, aggregated HE System controls should be integrated with trading (or VPP) platforms, via the available Application Programming Interface (APIs), to be discharged when threshold price levels are reached.

The pilot demonstrated the sub-minute response time, but the pilot Demand Response tests were long duration (60-120 minute) events, leaving the opportunity for future projects to test the value of more frequent real or near real time short duration (5 minute) events once automated[5].

The pilot did not fully explore the use of the battery fleet for Ergon Energy Network Demand Response. BESS have the potential to support Ergon Energy's low voltage network constraints by responding quickly to peak events and voltage fluctuations. Future projects should investigate how fleet managed BESS could be used with automated signals from Ergon Energy Network.

[5] The Australian Energy Market Commission announced on 28 November 2017 the change to the settlement period for the electricity spot price from 30 minutes to five minutes, starting in 2021. Five minute settlement is expected to provide a better price signal for investment in fast response technologies, including BESS.