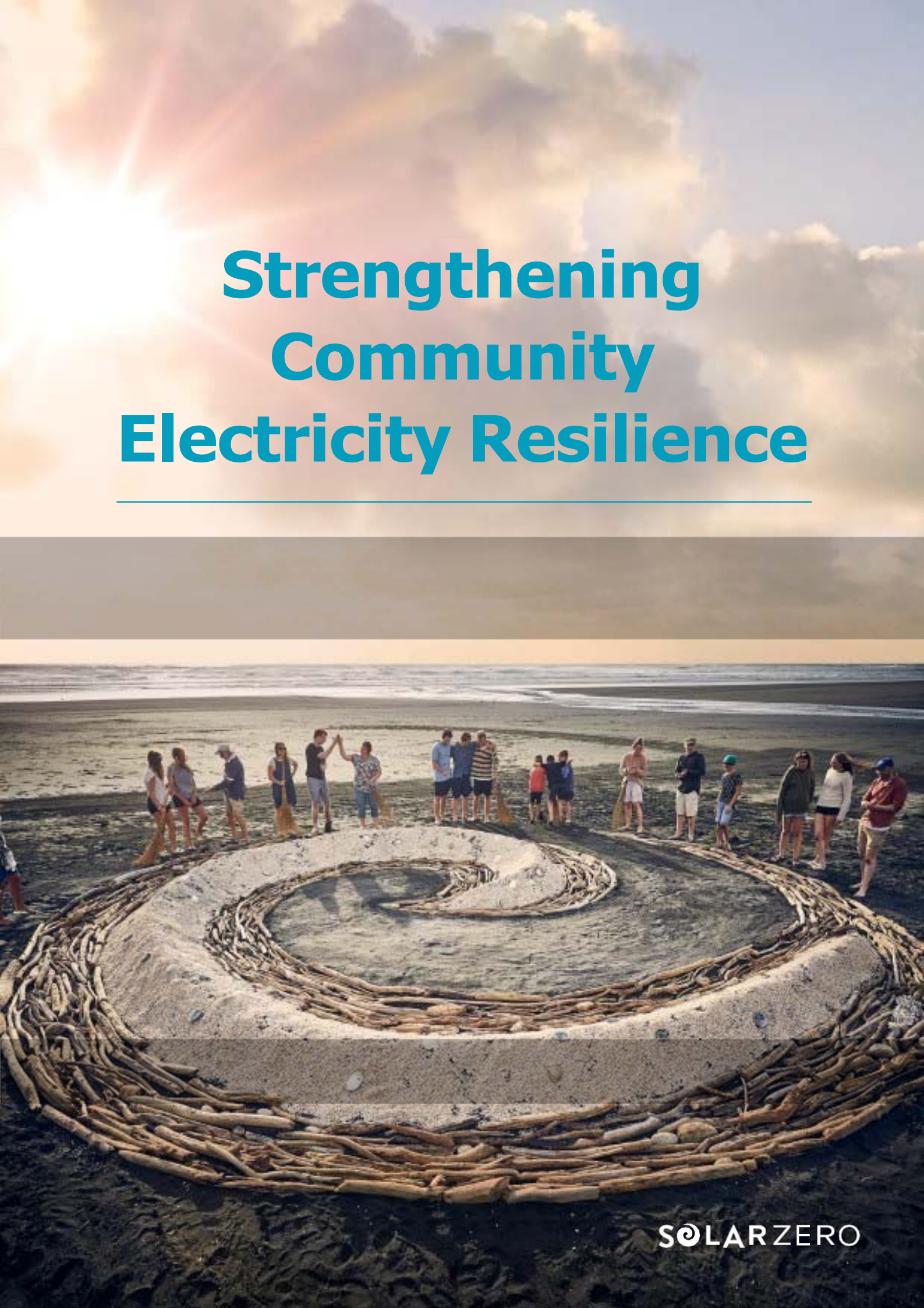
Strengthening Community Electricity Resilience



The report authors

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Chief Strategy Officer

Gareth Williams is solarZero's Chief Strategy Officer. He leads the development of the solarZero platform, new technology evaluation, R&D and design of our energy product and service. He has more than 20 years energy industry experience, with the last 10 years focussed on new energy technologies.
Gareth was GM of Strategic Solutions at Vector, the nation's largest lines company, where he led the development of strategies to manage the impacts of emerging technology trends and to develop strategy and lead implementation of "smart network" initiatives.

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Eric Pyle is solarZero's Director of Public Affairs and Policy. Eric has an extensive background in natural resource management and environmental issues. Prior to joining solarZero he was CEO of the New Zealand Wind Energy Association and, most recently, headed the Outdoor Access Commission.
Earlier in his career he led energy research policy at the Ministry of Research, Science and Technology and held roles with Forest & Bird, WWF and the central government natural resources sector.

Executive Summary

On February the 12th 2023, Cyclone Gabrielle reached landfall at the northern tip of Aotearoa New Zealand, inflicting widespread devastation. The cyclone caused historic and extreme levels of rainfall with river flooding and wind damage. Around 225,000 households suffered a power outage [1].

The electricity grid failed for one third of solarZero North Island customers, but due to the solarZero virtual power plant (VPP) technology – solar and batteries on residential homes – the lights stayed on and the freezers stayed cold. solarZero operates the largest VPP in Australasia, and this was its first test at scale. This Cyclone Gabrielle event shows that widespread adoption of solar, batteries operating within a VPP will enable communities to ride through major grid outages with core household electricity needs being met.

Ahead of the cyclone, solarZero activated its VPP to maximise back-up power to thousands of homes equipped with its solar and battery platform. Using cutting edge technology, all solarZero systems were remotely instructed to maximise energy storage at each site, increasing every home's energy independence and security.

The VPP successfully worked as designed, powering households through the cyclone, keeping the power on for over 2,700 families for the grid outages – in some cases as long as 5 days. In addition, solarZero households were able to support their community during this emergency.

This paper details how the VPP performed technically during and after the cyclone and provides consumer insights on how the solarZero platform helped communities address the challenges they faced. It demonstrates the importance of distributed solar and batteries providing household resilience and details how our VPP technology provided power to households when the grid went down.

It recommends that Aotearoa must coordinate and accelerate the adoption of behind-the-meter solar and storage VPP platforms as areas to invest in. The paper recommends a series of forward-looking initiatives to accelerate the development of Distributed Energy Sources (DERs) and the adoption of community-led VPP solutions. So we can build back better and develop a more resilient power system for households and communities.

[1] https://www.stuff.co.nz/national/131225113/power-outage-by-cyclone-gabrielle-the-largest-since-cyclone-bola

solarZero VPP:

Technical performance and Customer Insights

Design and operation of the VPP

The solarZero solar and battery platform is designed to lower the cost of electricity for communities and provide energy independence and security. During a power outage, the platform instantly disconnects from the grid and provides backup power to the home. This means that key designated appliances keep running without interruption. The battery recharges from its solar system to power homes.

During platform installation, solarZero identifies with each customer which critical circuits in their home should be powered during a grid outage. In addition to lighting circuits customers normally select the fridge, freezer and communications as key designated appliances/circuits. Large loads, such as immersion hot water heating and ovens, would drain the battery too quickly, so are not connected to the battery system.

When a storm is forecast solarZero instructs batteries to maintain a high state of charge. This ensures batteries can keep critical loads powered during the worst of the storm. Then, as it passes, they're are able to recharge from solar generation during the day, continuing to provide power for several days or more until grid power is restored.

The solarZero platform architecture is designed to operate remotely if it loses communication with central fleet management servers. It's also equipped with 3G communication as backup in case local fibre and wired connectivity goes down.

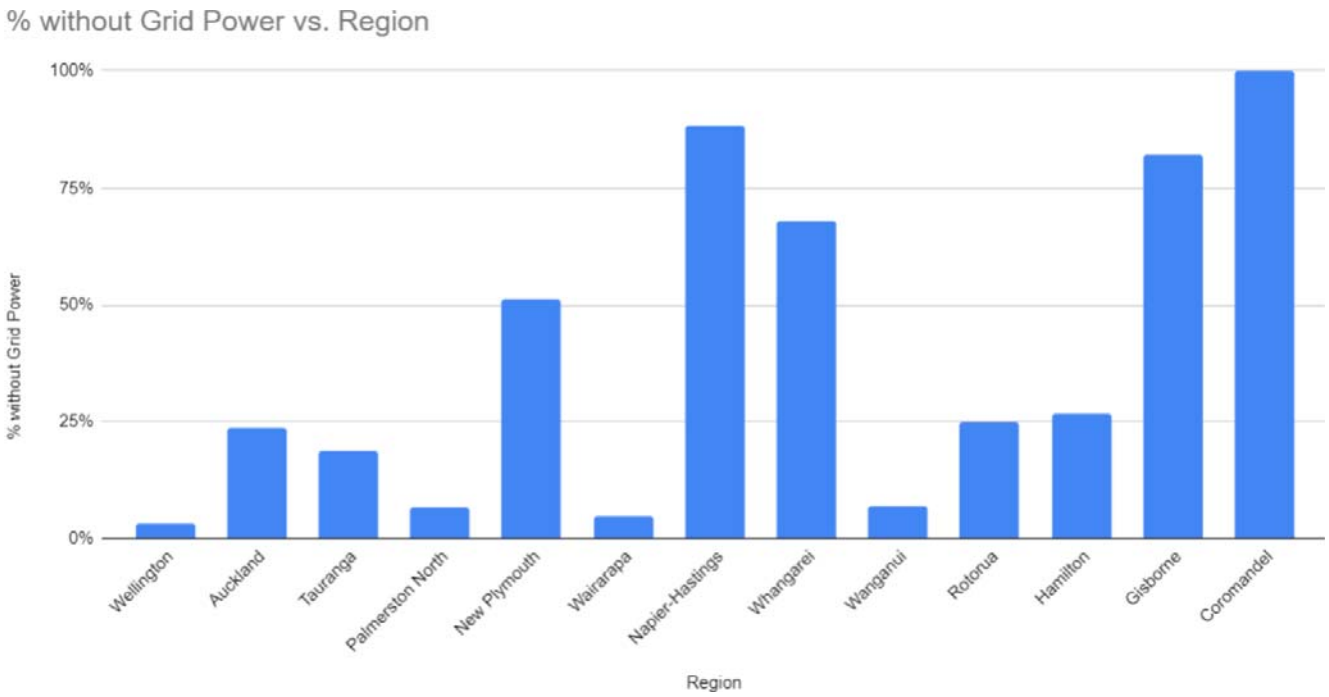
Results

During the week starting February the 6th, solarZero's fleet management team tracked Cyclone Gabrielle's predicted path as it neared Aotearoa New Zealand. As it became clear that this would be a major weather event for the North Island, a decision was taken on Sunday, February the 12th to prepare our VPP for likely power outages.

Batteries across the North Island were instructed to charge to 90% full across 24 hours in the forecast path of the storm. This ensured the VPP retained a high state of charge as the Cyclone moved across the country.

Overall statistics

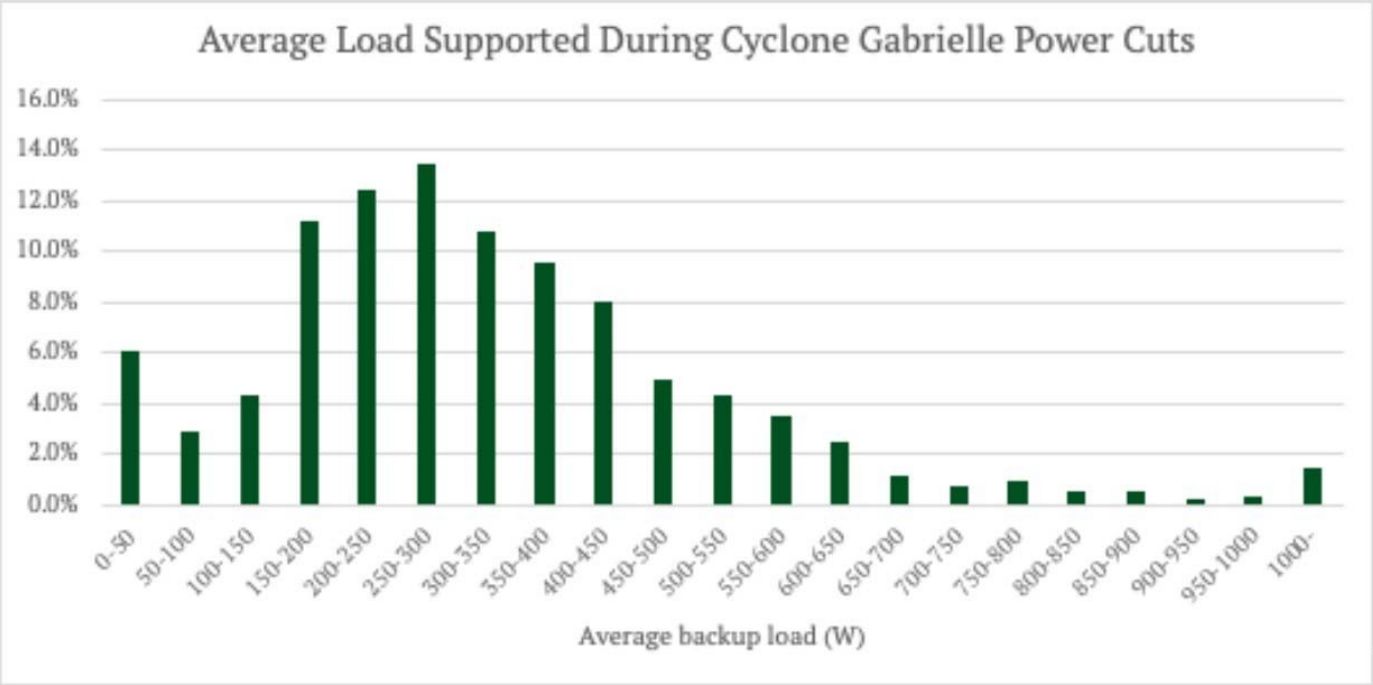
During the cyclone and its aftermath, 31% of solarZero customers in the North Island experienced a power cut of normal grid services. That is over 2,700 solarZero customers. The fleet of batteries was able to support customers' loads for more than 96% of the time.



The average duration of North Island power outages was 20 hours. In the Hawke's Bay area, 87% of customers experienced a power cut with an average duration of 51 hours.

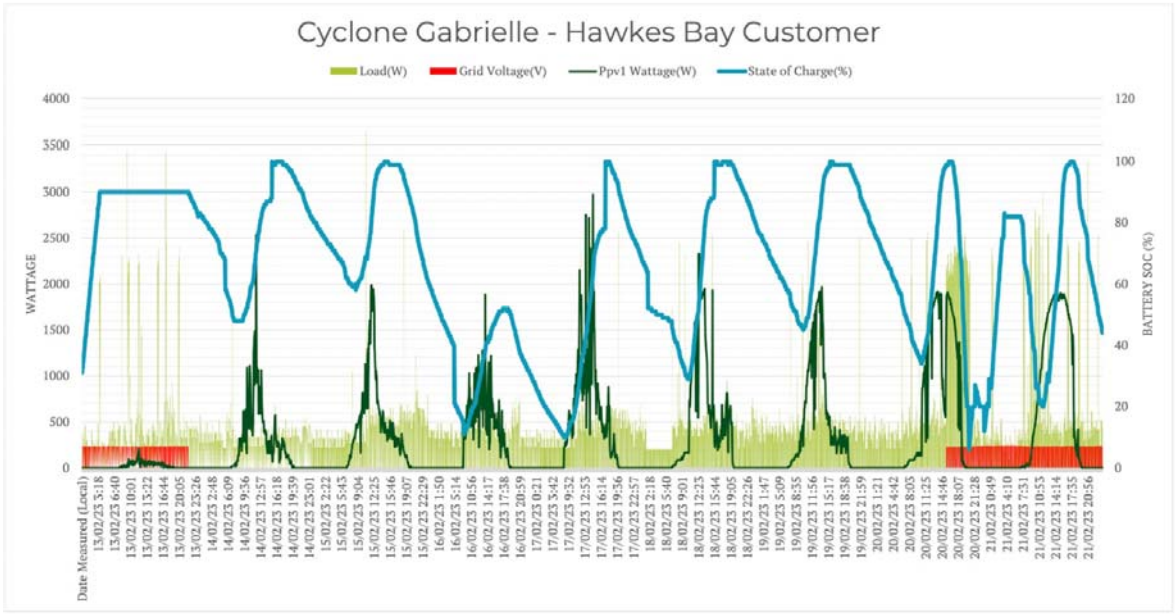
Outage Duration Hours	% of Outages	Cumulative
0-12	68.4%	68.4%
12-24	10.6%	79.0%
24-36	5.9%	84.9%
36-48	3.1%	88.0%
48-60	2.0%	90.0%
60-72	1.6%	91.6%
72-84	0.5%	92.0%
84-96	1.7%	93.7%
96-108	1.1%	94.8%
108-120	0.5%	95.3%
120-132	1.3%	96.6%
132-144	1.1%	97.7%
144-156	0.3%	98.0%
156-168	0.8%	98.7%
168-180	0.2%	98.9%
180-192	0.2%	99.0%
192-204	0.1%	99.1%
204-216	0.1%	99.2%
216-228	0.8%	100.0%

The total amount of backup power provided to help our customers power through these outages across the event was 9.3 MWh (3.1 MWh in Hawkes Bay) and the average load supported from the battery and solar during power cuts was 350W per hour, which is equivalent to around 40% of the electricity a customer would typically use at this time of year from the grid if it had been available.



During the event

Customers in Hawke's Bay were impacted more than most by the Cyclone. The customer below is a typical example of how the platform worked for the nearly seven days they were without grid power.



Graph showing a household's battery storage, solar production and power usage during Cyclone Gabrielle. The household lost grid power at

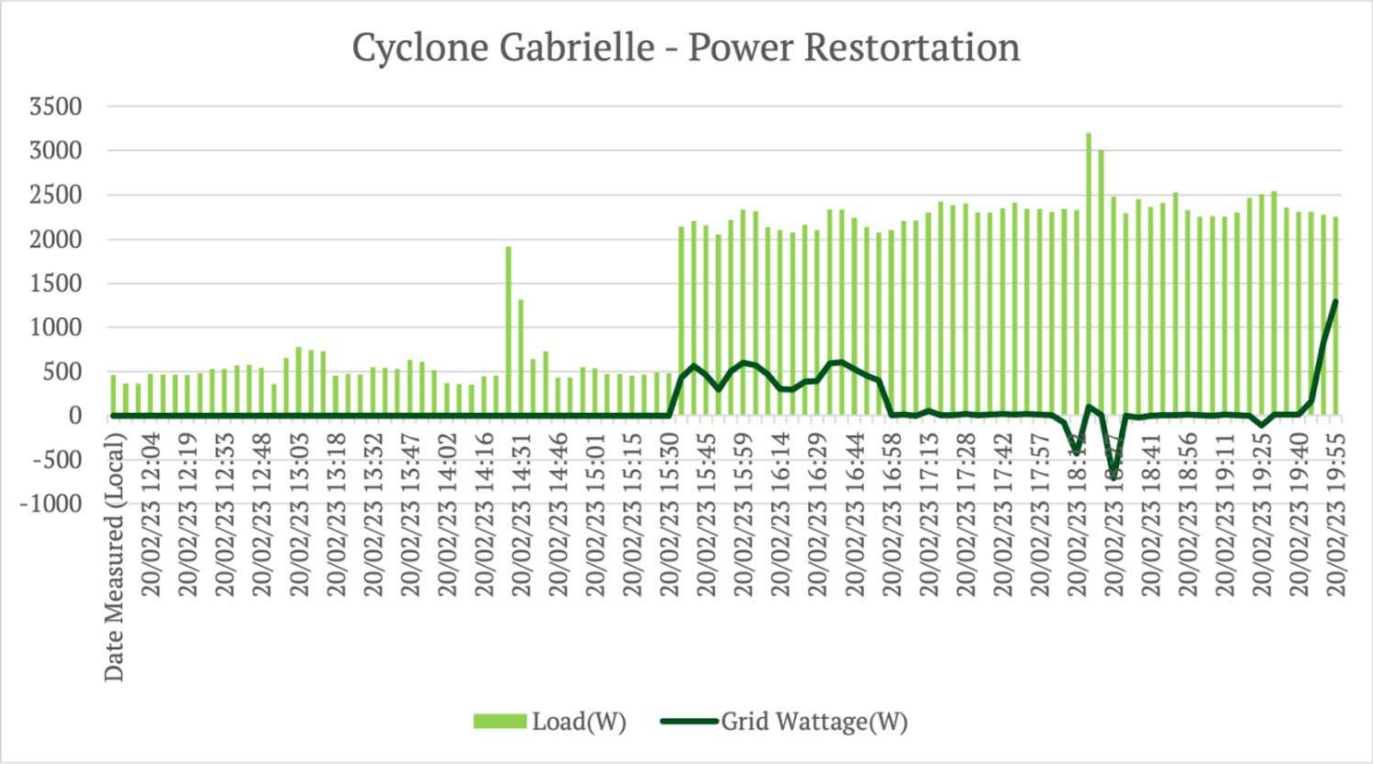
The battery charged to 90% full as per the instruction to the VPP as solarZero watched Gabrielle develop and move towards Aotearoa New Zealand. When power was lost on Monday evening, the customer's loads on the critical circuits continued to be powered, with the battery remaining above a 50% charge over the first night. The next morning the battery was fully recharged by solar energy. This cycle repeated itself until grid power was restored. At no time across the almost seven days without power did the customer run out of available battery storage. All achieved without any petrol or diesel generation.

While there were reasonable solar conditions after the cyclone, production was only around 60% of maximum. This 3 kW array produced less than 2 kW most days as a consequence of the cloudy conditions.

Each day the solarZero platform provided an average of almost 10 kWh of electricity to support key functions like internet connectivity, lighting, refrigeration, television and occasional bigger loads like a microwave, toaster and kettle.

Restoration of grid supply

After extended power cuts built up demand for using hot water cylinders, freezers, refrigerators, and so forth, places high demand on the network when power is suddenly restored. We learned from the Cyclone Gabrielle event that the solarZero VPP system supports networks during the restoration of supply after a sustained outage.



For our example customer in Hawke's Bay, when power was restored during the late afternoon on February the 20th, there was an instant increase in load in the home. Our platform, however, placed minimal demand on the network during the re-start and for the next five hours as most of the load could be supported from the solar and battery system.

Customer insights

Erin, Huntly

Living rurally, Erin was all too familiar with power cuts and everything taking that much longer to fix than those living in the 'burbs. So she knew having an off the grid power solution was key to keeping things moving at home. Having solarZero installed at their rural home means Erin no longer worries about being without power and being able to provide for her community in times of need. During Cyclone Gabrielle, fallen trees had affected the main power lines in Huntly, which was news to Erin and her husband Rob who had wondered why their house was the only one in the area still with the lights on "Oh, Huntly all looks out in the dark, what's going on? – Oh yeah, we've got solar!". Erin and her family helped the local community during this time, charging mobile phones, providing connectivity and supporting a family with a new baby.

Watch Erin's story *here.*

Anne, Northland

Living in beautiful Northland means Anne's home is exposed to all types of weather, making it vulnerable to power outages – however with solarZero Anne no longer has to worry about the weather determining whether she can turn the lights on. Recently her place was exposed to crazy weather conditions and here's what she had to say about solarZero. "The weather was really rough. I had three trees blown down. Everybody else around me was without power but I had some, thanks to the solarZero smart battery, so I was very lucky."

Read more

Grant, Hawke'sBay

Grant's Hawke's Bay household became a base camp for their neighbours without power. "It was the least we could do. Anything to help people… internet, somewhere to sit, relax and watch the news." According to Grant, during Cyclone Gabrielle "the smart battery saved us over the last two weeks. We managed to get it charged up when the sun was shining, allowing our neighbours to plug in their fridges, phones, devices and other essential items, because we were generating enough power to keep the battery at full capacity. " With power outages leaving so many in his area without electricity, internet or warm meal, Grant and his family jumped into action, with plenty of help from the solarZero smart battery backup.

Read more

Implications for Aotearoa New Zealand's power system

Climate change will increasingly challenge our existing infrastructure as storms become more extreme [2]. With its rugged terrain and dispersed population Aotearoa New Zealand faces some unique challenges maintaining infrastructure as storm severity increases.

The lesson learned from the solarZero VPP during Cyclone Gabrielle is that new technology can massively improve household and community wide resi lience. We can now keep the lights on, the fridges and freezers running, and communications going using solar and batteries whereas in the past once the power network was damaged that was it: the power was gone.

Could VPP technology help provide electricity for emergency centres?

Absolutely, yes. solarZero is working with emergency agencies to define the power usage profile of emergency centres, the kinds of buildings used as community energy centres, such as marae, schools, or gymnasiums.

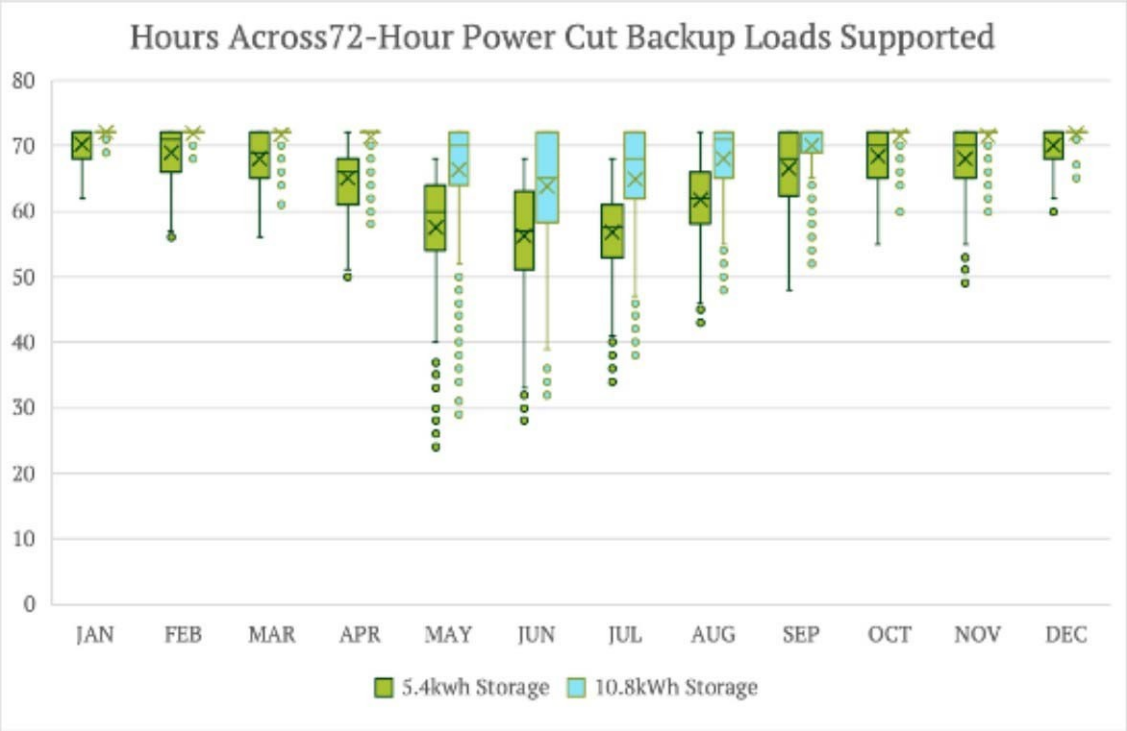
The Cyclone Gabrielle response illustrated flying fuel into isolated emergency centres was challenging. For example, there were other calls on helicopters. Solar and batteries operating as a VPP at a community emergency centre will reduce the need for fuel for generators and/or improve electricity availability for the centre. As the lessons from Cyclone Gabrielle are learned and analysed, we will work with emergency agencies to explore designs for solar/ battery VPP technology for emergency centres.

What about a natural disaster in winter?

Cyclone Gabrielle occurred in summer, and was followed by some days of moderately sunny weather. But what happens in other times when, for example, an earthquake hits in the middle of winter? We have not experienced a widespread natural disaster in winter – the Cyclone Gabrielle event is the first time the solarZero VPP has been tested over a wide scale.

Based on the data collected during the Cyclone we have modelled how effectively solar and batteries could support a minimum household load in winter. What the modelling results show is that the optimal size for a battery is 10.8 kWh to significantly improve the availability of the battery to support backup regardless of season. There are diminishing returns for batteries larger than that size.

[2] https://www.stuff.co.nz/environment/climate-news/131161918/climate-change-added-24cm-of-rain-to-aucklands-storm-researcher-says



Graph showing that in winter with 10.8 kWh of battery storage, availability through winter increases to around 88%. In other words, a power cut in winter would on average be able to support 350 W of backup load for 88% of the time across a 72-hour power cut.

Immediate choices - hardening networks, VPP or a combination of both?

The VPP technology has proven its important role as part of the power system during Cyclone Gabrielle. The electricity industry faces a choice in how we rebuild after the Cyclone and how we prepare for future more severe weather:

- Continue to harden networks by investing in old technology that will fail in the face of bigger and bigger storms; or Strengthen the power systems by supporting the uptake of new technologies that will enable communities and businesses to ride through storms with minimal disruption to their core electricity needs.
- Now that the kind of VPP technology pioneered in Aotearoa New Zealand by solarZero is proven, policy and regulatory agencies need to work out how to incentivise and support lines companies to encourage the uptake of this technology by households, communities and businesses.

What we have learned from storms and earthquakes in Aotearoa New Zealand is that few areas are immune to large scale natural disasters that will disrupt the power system. For example in January and February 2023, even significant areas of Auckland suffered power cuts and the Christchurch earthquake took out power across significant areas of the city.

Transpower and lines companies are beginning to look at non-network solutions (NNS) to defer upgrades of power systems. To date NNS have been focused on growth-related investments in infrastructure. The same thinking can be applied to network investments related to resilience.

The traditional way of thinking about reliability – System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI), need to be reconsidered. For example, if a feeder has a very high proportion of households with solar and batteries, can the standard reliability metrics be relaxed if it would be very expensive to meet them? Intuitively it makes sense that in some areas it is more cost effective to support the uptake of solar and batteries from a resilience perspective than to invest in hardening the network. In other words, use a resilience-focused non-network solution.

Now that VPP technology has been proven from a resilience perspective, the Electricity Authority, the Commerce Commission and lines companies need to develop a framework to specifically identify the tradeoffs between hardening networks and supporting the uptake of solar and batteries.

Innovation - microgrids as part of the future

VPPs could also be enabled to share solar and storage across communities. Homes and/or critical facilities equipped with solar and batteries, such as evacuation centres, fire stations and schools, could provide electricity to all homes sharing an islanded circuit in the neighbourhood during a blackout via microgrid technology.

Microgrid technology is cutting edge and will be part of the power system of the future. As technology evolves, it will become possible to form smaller energy networks to safely supply local energy backup solutions such as home or community solar with storage.

The following actions are needed to enable a microgrid future that can build community resilience in the face of climate change:

- R&D funding via the innovation system to support engineering research at universities and Callaghan Innovation.
- Innovation funding and pilots to help build industry capability, demonstrate the technology and to learn how to make it work in practice.
- Policy and regulatory change to enable this technology to be deployed into the power system.

[2] https://www.stuff.co.nz/environment/climate-news/131161918/climate-change-added-24cm-of-rain-to-aucklands-storm-researcher-says

Conclusions and Recommendations

During Cyclone Gabrielle VPP technology provided electricity resilience solutions for households and communities. This kind of technology can help reduce or even prevent power outages for homes, schools, businesses, and other important community facilities.

Recommendations:

- **Non-network solutions - recognition and policy:** DERs and VPPs should be recognised by the Commerce Commission as an alternative to 'hardening' electricity infrastructure. The Commerce Commission should ensure that lines companies prioritise funding for non-network solutions to strengthen community resilience.
- **Non-network solutions - economic support for consumer adoption of DERs and VPPs:** To reach penetration levels of DERs on feeders to enable sufficient resilience and in the future sustain 'islanded' communities will require many rooftop solar and battery storage systems along individual feeders – potentially requiring the majority of homes to have this technology. To accelerate adoption, a non-network mechanism should be created to support local resilience instead of or alongside traditional network hardening.
- **Government solar initiatives:** Government-funded solar initiatives should include a battery and interconnection into VPP platforms.
- **Community centres:** Funding should be made available for VPP enabled solar and battery systems on community centres used for emergencies, such as schools and marae. The solar/battery system can be used to supply power during normal operation and a portion of the system funded to provide extra capacity for times of emergency.
- **Micro-grids pilot:** A cross industry pilot programme should be launched to prove and demonstrate this technology with some practical implementation projects. The micro-grids should be funded to establish the technical and policy constraints and solutions to providing energy at a community level.
- **Pre-wiring for solar batteries:** A constraint to the uptake of solar is the cost and difficulty of running cables in households for solar and battery systems. The cost of doing this during construction or major renovations is very low – a few hundred dollars. All new building, commercial and industrial should be pre-wired and engineered for solar and storage.
- **Fast track regulatory changes**: Enable a full set of revenue streams available to VPPs to open so that these new platforms can be deployed to help create a much more efficient and reliable power system, as the economy is electrified.