# Virtual Power Plant in South Australia

## Stage 2 Public Report

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# Executive Summary

This milestone report describes AGL's progress against the Stage 2 objectives of the 5MW Virtual Power Plant in South Australia and is submitted in partial fulfilment of AGL's knowledge sharing obligations to the project's funding partner, ARENA.

The project comprises the installation and orchestration of a 5MW VPP consisting of up to 1,000 residential energy storage systems installed behind the meter, and capable of dispatching up to 12MWh of stored energy. The project was established to demonstrate the role of virtual power plants in enabling higher penetrations of distributed renewable generation in the grid and help further understanding about the role of distributed 'smart' storage in supporting grid resilience and reliability in South Australia.

AGL has successfully completed Stage 2 of the three-stage deployment of energy storage systems. As at 31 May, 312 batteries had been installed in customer's homes and the rollout of new technology energy storage systems is progressing to a revised deployment plan considering hardware stock availability and certified installation resources. Initial trials have demonstrated that the VPP can respond as expected to both planned and unplanned dispatch events and has the potential to respond rapidly enough to participate in the 6 second contingency FCAS market.

### Stage 2 Achievements

- Installations – more than 300 energy storage systems have been installed in customer premises.
- Sales – more than 700 batteries have been sold, and more than 500 requotes have been completed, where customers chose to upgrade to the newest technology available as a part of the program. Lead generation continues for the final tranche of customers with more than 800 leads generated. This has been assisted by news coverage and energy storage media coverage particularly in the lead up to the South Australian election in March 2018.
- Delivery and installation – AGL has seven trained installation crews and is ramping this up to ten crews. AGL has the capacity to install up to 20 batteries per week and this will increase further as the project continues.
- Stakeholder Reference Group – Three successful Stakeholder Reference Group (SRG) meetings have been held.
- Knowledge Sharing – Presentations on project progress have been made to, among others, the Australian Energy Storage Conference and NEM Future Forum.
- VPP Performance – The project has conducted demonstration dispatch events during 2017 and 2018 and has monitored the impact of the VPP on network load and site exports as well as the impact of local grid conditions on individual energy storage systems and fleet performance.

### Next Steps

Stage 3 of the project will focus on completing the remainder of the 1,000 installations and further demonstration of VPP functionality for a number of network service and wholesale participation use cases.

# 1 Introduction

## 1.1 Project overview

AGL's Virtual Power Plant (**VPP**) remains a key demonstration project as Australia's energy markets continue to evolve. The business model that underpins the VPP presents important opportunities for delivering more reliable energy supply, empowering customers and contributing to the national policy debate regarding the National Energy Guarantee (**NEG**).

As the cost of distributed energy resources (**DER**), including energy storage systems, continues to decline, the increasing accessibility of these technologies enables traditional energy market participants and new entrants to provide a range of new energy services offerings. In addition to allowing customers to more actively manage their own energy needs, DER are also giving rise to new kinds of demand-side participation, enabling customers to contribute system-wide benefits through dynamic programs. The once linear supply chain is becoming increasingly decentralised and bi-directional. A more efficient deployment and use of DER will enable co-optimisation across these multiple uses and value streams, including the management of broader system needs.

AGL sees competition and innovation in technology and business models as the primary means for meeting this co-optimisation challenge and aligning the interests of energy service providers with those of the customers they serve. AGL's VPP presents one such model, demonstrating at a commercial scale the potential to orchestrate multiple DER to provide network services and wholesale market participation.

As the national policy debate regarding the NEG settles, AGL anticipates that retailers will look to develop a range of innovative products and business models to meet their reliability obligation at least cost. Business models that entail a behind-the-meter orchestration function, such as a VPP, could play an important role in enabling dispatchable capacity when the system needs it.

AGL's VPP seeks to demonstrate the value that grid-connected batteries can create for a range of stakeholders when managed as part of a co-ordinated program. Stage 2 has seen the introduction of updated energy storage technology and further demonstration of wholesale market dispatch events.

This report focuses on description of learnings from ESS installations and additional demonstration events, and as well as an in-depth analysis of voltage observations.

Since AGL's last milestone report, AGL's VPP has faced several hurdles. High voltage levels in many parts of the distribution network regularly affect some customers by making their ESS systems inoperable. During voltage excursions, customers' inverters disconnect from the grid, making them unavailable to the VPP. At times when customers are exporting power into the grid, voltage levels are increasing further. Policymakers and network businesses alike will need to consider these issues to facilitate the viability of the virtual power plant model into the future.

AGL has now completed Stage 2 of its South Australian VPP, with the sale of over 700 and the installation of over 300 Energy Storage Systems (ESS) as at 31 May 2018.

The following value streams have also been demonstrated using the VPP:

| Value Stream | Recipient | Status |
|---|---|---|
| Increasing solar self-consumption | Consumer | Functionality demonstrated through ongoing performance monitoring. |
| Utilising backup power in the event of an outage | Consumer | New technology now being rolled out has increased backup functionality now being used by customers. |
| Network support through peak demand management | Network service provider | Capability demonstrated through VPP activation events. |
| Network support through frequency control services | Network service provider | Capability demonstrated through VPP activation events. |
| Physical hedge or arbitrage opportunity in wholesale energy market | Retailer | Capability demonstrated through VPP activation events. |

## 1.2 Review of Stage 2 Objectives

The primary objectives for Stage 2 were to complete the installation and commissioning of 300 Energy Storage Systems (ESS) and to demonstrate the use of these as a VPP. These objectives have been achieved.

Overall project performance against milestones has been as shown below:

| Stage | Installation target | Completion date | Completed installations | Achievement Date |
|---|---|---|---|---|
| Milestone 1 | 65 | 28 Feb 2017 | 150 | 30 Apr 2017 |
| Milestone 2 | 300 | 31 May 2018 | 312 | 31 May 2018 |
| Milestone 3 | 1,000 (min. 950) | 31 Dec 2018 | | |

As at 31 May, a total of 312 ESS were installed and working. Test dispatch events were undertaken through 2017 and 2018 and the results of these are discussed in section 2.7.

There were also several secondary objectives in Stage 2. A review of the program's performance against these is as follows:

| Objective | Result |
|---|---|
| Consider integration of new energy storage systems from suppliers other than Sunverge, if Recipient determines technically and commercially feasible. | Tesla and SolarEdge/LG Chem are now included in the program. |
| Begin targeted deployment of energy storage | The rollout of Tesla and SolarEdge/LG Chem systems in the field is now well advanced. |
| Begin targeted deployment of energy storage systems in specific network areas | Deployment of ESS to small geographic areas in the quantities required to deliver network benefits has proved challenging. This is discussed further in section **Error! Reference source not found.**. |
| Refine targeted marketing channel | Marketing channels now well-defined and working. |
| Bed down operational systems and focus on driving down operating cost | Significant improvements have been made in the operational fulfilment of ESS resulting in an increase in deployment capacity from approximately 5 ESS per week to up to 20 per week.<br>A significantly lower cost of installation due to smaller form factor batteries has also been achieved in Stage 2. |
| Demonstrate more sophisticated VPP capability | VPP capability has been demonstrated. |
| Consideration and planning of Stage 3 technology options to determine technical and commercial feasibility | Well advanced on the selection of new VPP orchestration software for use during Stage 3. |

# 2 Current Stage Review

AGL has now completed more than 300 ESS installations and has sold a further 400 ESS units that are being deployed in customer's homes at a rate of 15 - 20 units a week.

## 2.1 Inclusion of new ESS technology

In March 2018, AGL added two new technologies to the SA-VPP program. Following a thorough selection and technical due diligence process, Tesla's Powerwall 2, and LG Chem's RESU10H batteries paired with a SolarEdge inverter were made available to customers as part of a next generation technology offering.

These new technologies reflect advancements in the market since the program was launched. The new products provide customers with up to 35% more capacity as well as improved backup functionality. Customer feedback regarding the new technology options has been overwhelmingly positive.

Early VPP customers who had a Sunverge ESS installed have been offered a free upgrade to their choice of new technology.

Customers who had paid a deposit for the previous technology, and had been waiting to have a system installed, have now been contacted and progressively requoted on their choice of Tesla or LG Chem/Solar Edge product.

## 2.2 Technology selection process

The technology selection process for new ESS technology involved four key stages:

<u>Market survey</u>

Based on learnings from the first phase of the program about ESS features that support consumer value and both network support and wholesale participation use cases, an extensive market survey exercise was undertaken focusing on a review of technology capability and specifications, including:

- compliance with Australian and international safety and performance standards.
- vertical integration of inverter control through an Application Program Interface (API)
- availability and distribution networks in Australian market
- vendor experience and support networks to deliver a 'best in market' customer experience
- ESS size, weight and complexity of installation
- quality of manufacture and warranties offered including performance
- physical integration of componentry such as the inverter backup capability
- three-phase site monitoring (including three-phase solar inverters)
- cost

Technical due diligence

AGL installed test units from shortlisted vendors in its energy storage lab at 699 Bourke Street in Melbourne and in a limited number of residential homes. The purpose of this testing was to validate ESS performance and trial the hardware installation. Key focuses included:

- vendor supplied performance data
- installation process
- safety response validation to faults conditions:
  - loss of grid
  - response to high and low grid voltage
  - response to power limitations
- performance baselining:
  - confirmation of charge/discharge power capabilities
  - confirmation of response to a range of loads and changes in load on a range fo timescales
  - ESS performance during low states of charge and low rates of discharge
  - verification of changeover to backup power in the event of loss of grid.

Final selection

AGL's final selection was the Tesla Powerwall 2 and the LG Chem RESU 10H - SolarEdge combination. Multiple vendors were selected to mitigate the risk of supplier stock constraints, to demonstrate the orchestration of multiple hardware brands and technologies, and to support customer choice.

## 2.3 Technology Announcement

AGL announced the updated VPP technology in targeted communications by email, supported by website landing pages, with the objective of:

- announcing the new technology itself and communicating the opportunity to upgrade
- providing customers with sufficient information about the new product and clarity around the next steps to upgrade their ESS
- assisting with customer education about ESS technology available.


**VPP landing page – new technology announcement Tesla Powerwall 2**


**VPP landing page – new technology announcement LG Chem RESU 10H**

Around 97% of customers clicked through to review the product-specific landing pages to learn more. Customers spent a significant amount of time on each product page, investigating the new options and next steps. Following the targeted email, AGL's SA-VPP sales team made contact by phone to each customer, discussed their product and installation options with them, and arranged for an ESS upgrade quotes to be issued to the customer, if they chose to upgrade.

## 2.4 Sales

The addition of new battery technology to the SA-VPP program has been welcomed by customers and 'requoting' sales conversations have been less complex and considerably shorter than the initial sales calls. Brand recognition amongst customers is very high for both products.

The dedicated VPP sales team have found that many customers have a good working knowledge of ESS features and functionality and many already have a technology preference by the time the customer is called to discuss their product preference. Of the more than 700 battery sales made to date, more than 500 have been requoted and sold based on the new ESS technology.

## 2.5 Delivery and Installation Capacity

AGL has now trained seven installation teams in the safe delivery, installation and commissioning of both technology offerings. These teams are both CEC and ESS manufacturer-accredited.

An additional three teams, bringing the total to ten, will be brought on line shortly.

## 2.6 Sales and installation metrics

As at 31 May 2018, AGL had completed 312 installations and is currently installing at a rate of 15 - 20 per week, with a plan to increase this to 25 per week during June. Of the 312 ESS in the field at the end of May 89 were new technology installs, comprising a combination of greenfield sites and sites where the previous technology ESS had been removed.

Overall project performance against milestones has been as shown below:

| Stage | Installation target | Completion date | Completed installations | Achievement Date |
|---|---|---|---|---|
| Milestone 1 | 65 | 28 Feb 2017 | 150 | 30 Apr 2017 |
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## 2.7 VPP Performance

Over the summer of 2017/2018 the program had approximately 280 Sunverge systems in the field. The fleet's normal operating methodology is to reduce customer bills by maximising solar self-consumption. This it does by targeting a zero-energy draw from the grid, charging the ESS when solar production exceeds household load, and discharging the ESS when household load exceeds solar production. The aim is to have households with, on average, a lower peak demand and lower export peaks.

### 2.7.1 VPP Orchestration Events

AGL undertook a ten-day orchestration trial between 19 - 29 of December 2017. During the trial, ESS were directed to discharge with a site export target of 3 kW between 5pm – 6pm to demonstrate the fleet's ability to reduce the peak evening load on the grid from participating households.

The fleet's ability to meet the targeted export value varied depending on factors including the weather and customer load profile. These factors impact both the starting state of charge of the ESS fleet and the typical household load during dispatch.

Beginning on 19 December 2017, AGL performed ten days in a row of one-hour orchestration events between 5pm – 6pm, the time of peak evening load, where site export targets were set to 3kW. On a sunny day, the ESS were fully charged and the sites would typically have been exporting 1 – 2kW of solar before any additional ESS export. This meant that the ESS needed to contribute an extra 1 – 2kW of power over the hour.

### 2.7.2 Fleet Dispatch Details and Results

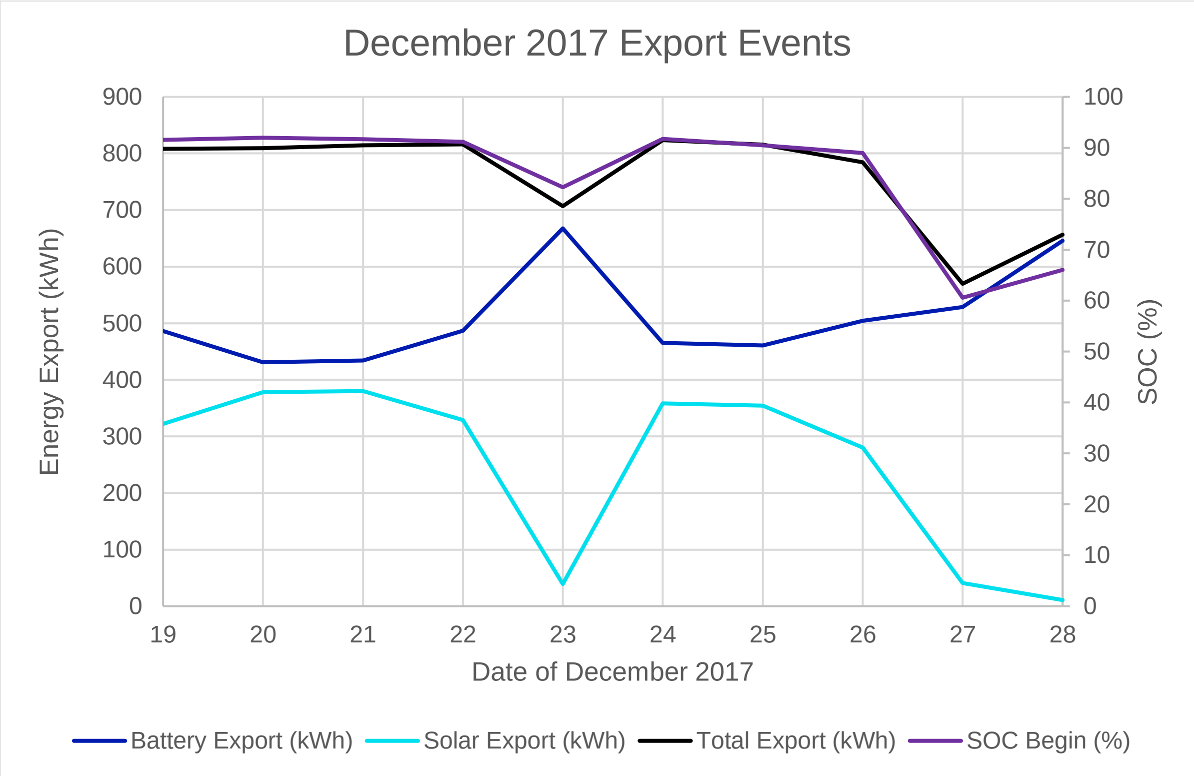


**Figure 1 – energy export on dispatch days**

The figure above is a plot of the energy exported from the sites for the ten events. Total Export is the total site energy that was exported, Battery Export is the ESS energy exported from the site, and Solar Export is the solar energy exported from the site. The purple line is the average state of charge (SOC) of the fleet at the beginning of the dispatch. Note how closely it follows the total site export.

The graphs below display a three-hour time window (4pm – 7pm) centred around one-hour dispatches. The top chart is how the mean behind-the-meter load is being served by the energy sources, green is load served by the PV, orange is load served by the ESS, blue is load served by the grid.

The middle chart shows which energy source is exporting from the site. The PV, in green, slowly decreases over the hour. The orange is the amount of ESS export required to make up the 3kW site export target. The bottom chart is the average SOC and grid voltage of the fleet over the three hours.

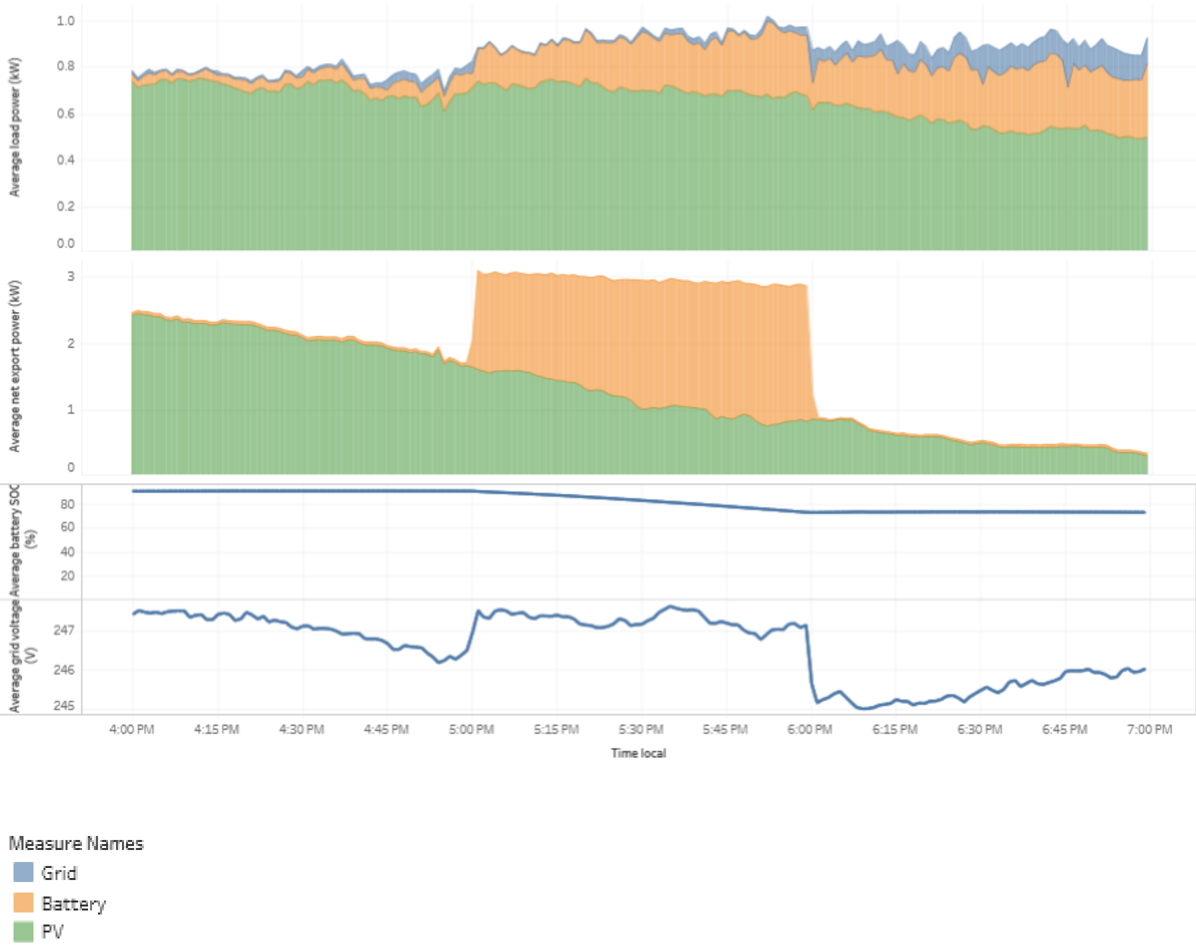


**Figure 2 – dispatch performance on a sunny day**

The Figure above shows a sunny day with solar generation before the evening export. The ESS were at or near full SOC and there was around 2kW of solar being exported just before 5:00pm. At the start of the hour the ESS added around 1kW of export, and ended the hour adding close to 2kW of export.

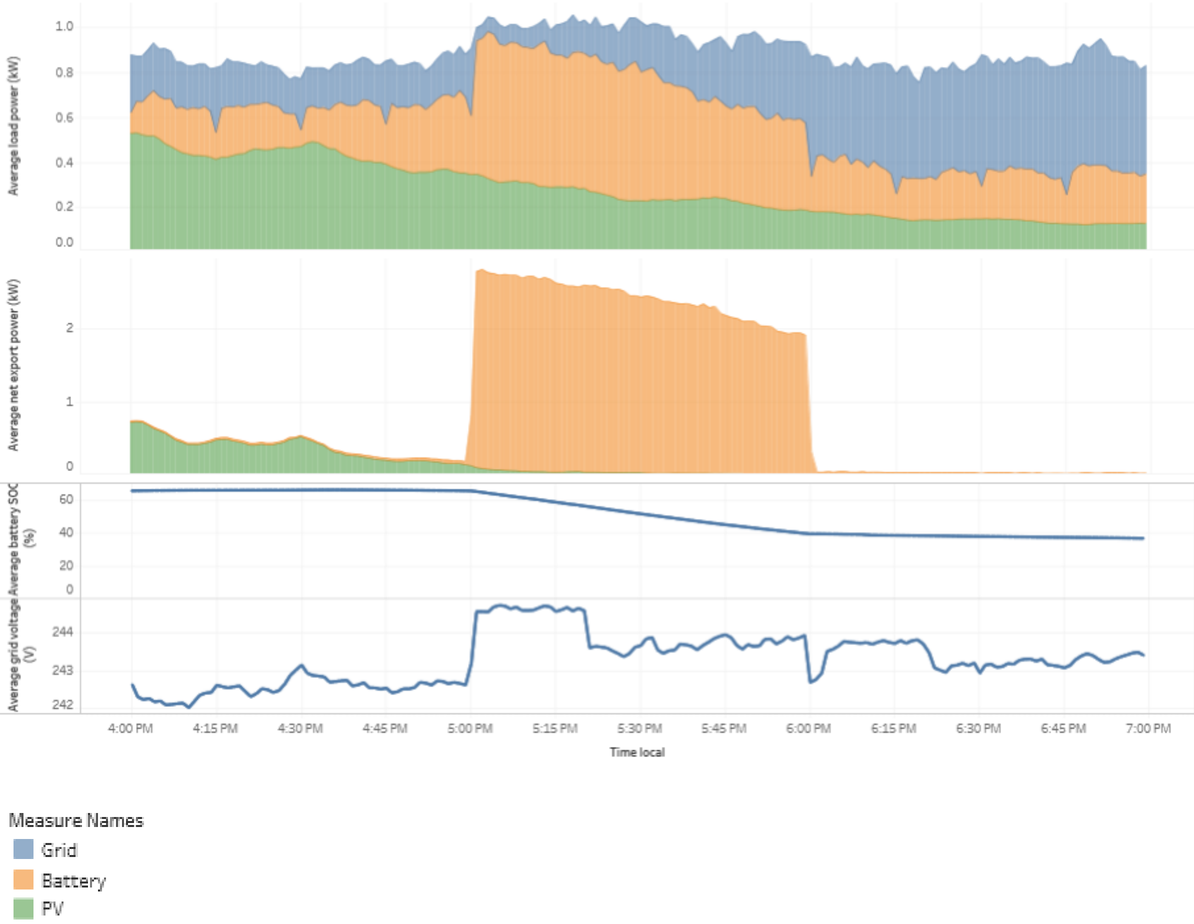


**Figure 3 – dispatch performance on a cloudy day**

The graphs above show a day with poor solar generation throughout the day and the ESS began the 5pm dispatch not fully charged, averaging 60% SOC. There was little solar export at the 5pm start time, therefore to meet the 3kW target the ESS provides almost all the site export, with limited contribution from solar at that time.

### 2.7.3 Key Learnings

There were several interesting lessons from these trials, the key one being that it wasn't possible to maintain a consistent 3kW export target over the course of the one-hour dispatches. The reasons for this include high grid voltage and SOC at a level where ESS stop exporting – but in addition sites with high loads did not meet the export target.

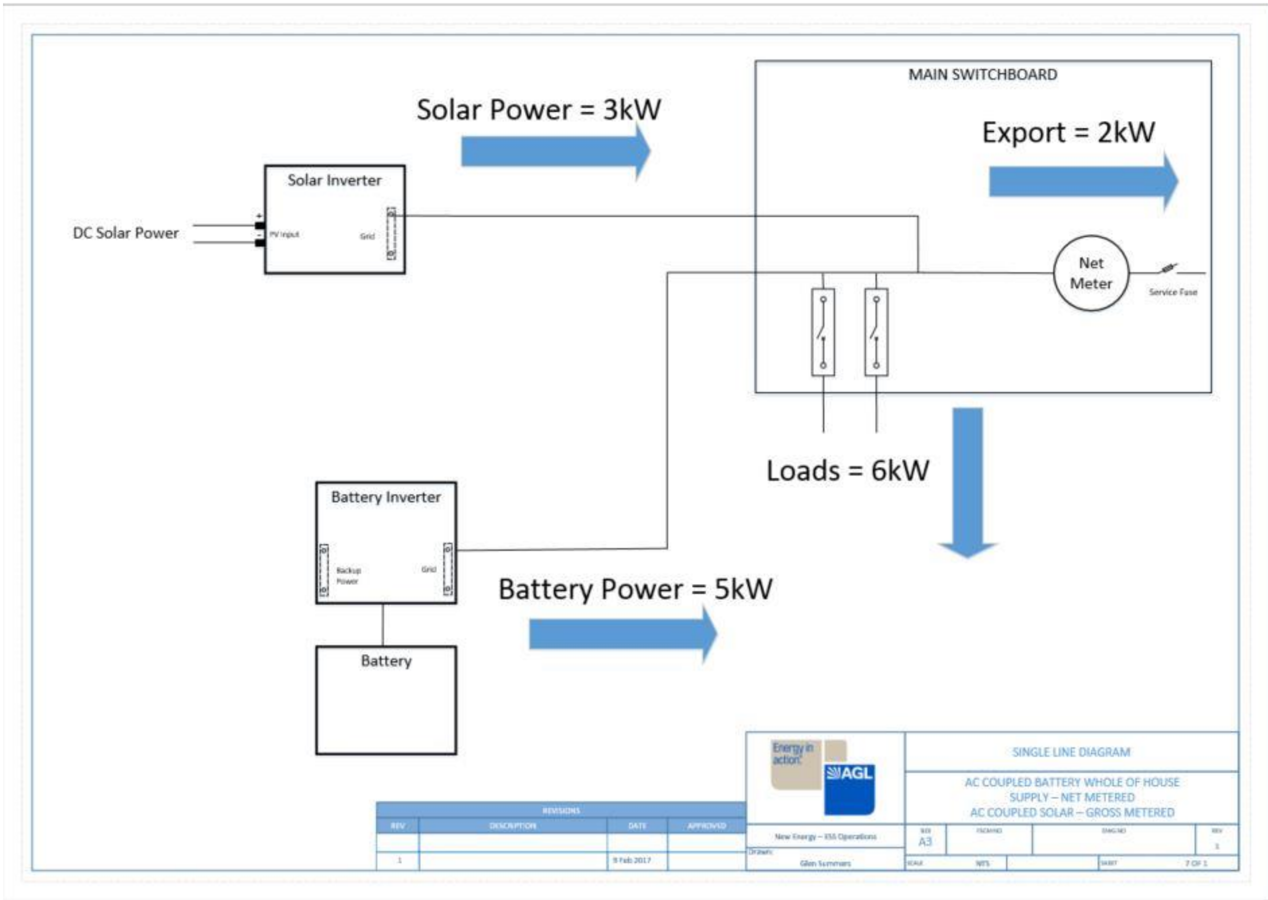


**Figure 4 – export power flow limited by load**

The figure above illustrates why not all sites could reach a 3kW site export target. If there is behind the meter load after being served by PV of greater than 2kW, the battery inverter capacity of 5kW limits the power system's ability to export the full 3kW.

Whilst the need for DNSP site export limits is understood, this trial raises a further question regarding battery inverter capacity limits. For example, a 10kW battery inverter would be better at providing 5kW of site export as it could better serve behind the meter loads while still having export capacity.

### 2.7.4 Day-to-Day Operation

In aggregate, the VPP significantly reduces the peaks in the loads drawn from the grid under the daily solar self-consumption operation. In the graphs below, the blue curve denotes the gross loads before solar (hypothetical), orange denotes the net loads if there was only solar (hypothetical), and then the green curves are the net loads with the ESS included (actual results).

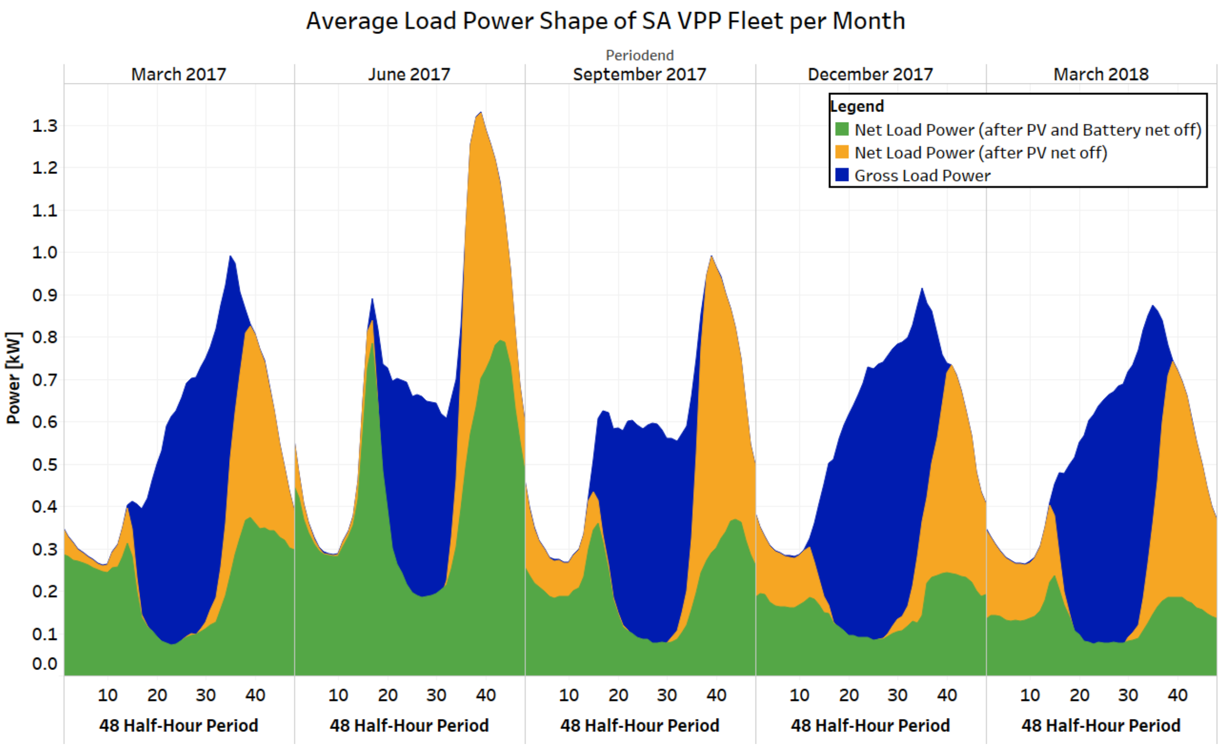


**Figure 5 – average fleet shape across the year**

The graph above shows the changing load shapes for March 2017, June 2017, September 2017, December 2017 and March 2018.

The blue curve is the gross load that the households use, which is what the grid would have had to deliver in the absence of any installed solar or ESS.

The orange curve is the load that would have occurred if the site had a solar system only installed. Through midday the load is significantly reduced, to almost zero (0.1kW average across the entire fleet, 0.2kW in June with the least amount of solar generation). However, the peak load drawn by the sites only slightly reduces. For example, it reduces from about 1kW to 0.8kW in March, and from slightly over 0.9kW to 0.75kW in December.

In June solar does not reduce the peak load at all, which stays slightly above 1.3kW.

The green curves show that adding the ESS significantly flattens the load seen by the grid.

December and March have aggregate load values of around 0.2kW. In June, with the reduced solar generation, the ESS are less charged and less able to shift load. The June peak of 0.8kW, with ESS included, exceeds the summer peak.

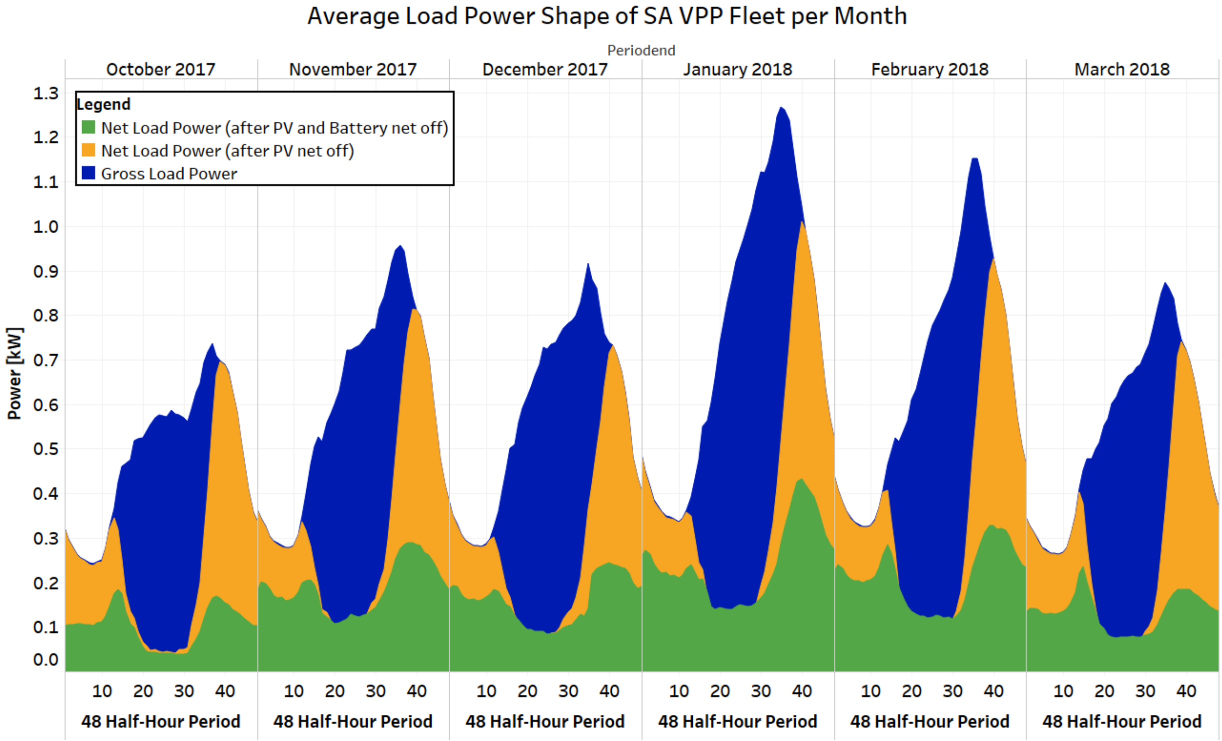


**Figure 6 – average fleet shape in spring and summer**

The graph above shows the same chart for spring and summer. January has the significantly highest gross load (blue) peaking at close to 1.3kW, though after the aggregated solar and ESS self-consumption, the peak load comes down to around 0.4kW.

These data provide evidence, as expected, of the benefit of ESS to significantly reduce the peaks in the loads drawn from the grid under the daily solar self-consumption operation, this is true compared to the counterfactual of these sites with no solar, and solar only.

### 2.7.5 Reduced Solar Export

There has also been a significant reduction in the solar exports to the grid. In the figures below the blue curve denotes the gross solar generation, orange curves denote the solar export that would have occurred with the site load but without the ESS, and the green curves show what happened in aggregate with the ESS performing solar self-consumption.

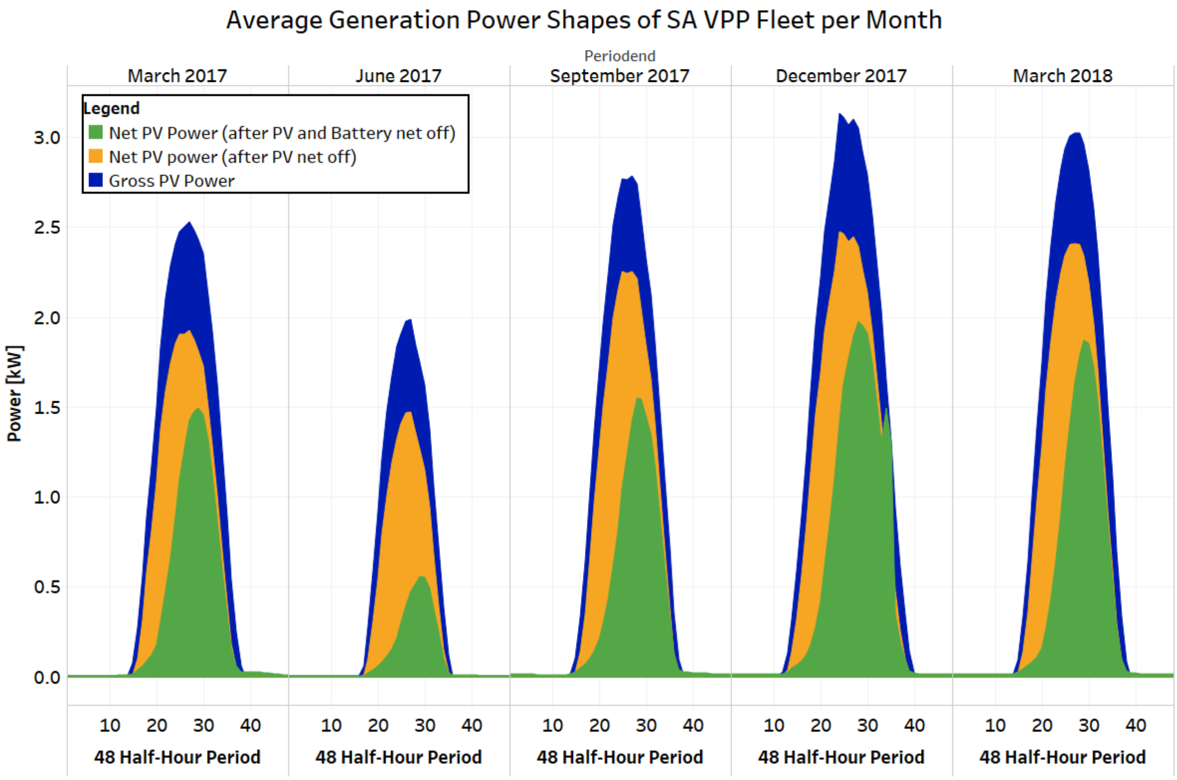


**Figure 7 – reduced solar export due to ESS**

The reduction in solar exported to the grid due to the ESS is clear from the figure above. The addition of the ESS reduced the peak export by around 0.5kW, bringing the peak exports in December 2017 and March 2018 down from around 2.4kW to 1.9kW. For sites that discharge their ESS each night, the larger ESS being installed later in our VPP program will reduce these exports even further.

### 2.7.6 VPP Performance Summary

The data shows that the ESS fleet has a high level of solar self-consumption, has reduced peak solar exports during the day and has flattened the daily load profiles, especially through summer.

## 2.8 Summary of Project Media

Most media for the VPP was concentrated around the initial announcement and commencement of the project (see Stage 1 milestone report), however there have been some stories in the media relating to the project in Stage 2. These include:

- The Advertiser – Major Projects Conference attendees to get AGL power plant update in Adelaide

http://www.adelaidenow.com.au/business/sa-business-journal/major-projects-conference-attendees-to-get-agl-power-plant-update-in-adelaide/news-story/dacd0a814f459dd9c6a10abaf6f623f1

- ABC News – AGL suspends household battery installations for Adelaide's cutting-edge Virtual Power Plant, 7 September 2017

  http://www.abc.net.au/news/2017-09-07/battery-scheme-under-the-spotlight/8883330

- Renew Economy – AGL hits pause on virtual power plant in technology “rethink”, 29 August 2018

  https://reneweconomy.com.au/agl-hits-pause-on-virtual-power-plant-in-technology-rethink-57487/

- Renew Economy – AGL switches to Tesla and LG Chem for virtual power plant, 13 March 2018

  https://reneweconomy.com.au/agl-switches-to-tesla-and-lg-chem-for-virtual-power-plant-77717/

- The Conversation – The unholy alliance that explains why renewable energy is trouncing nuclear, 20 March 2018

  https://theconversation.com/the-unholy-alliance-that-explains-why-renewable-energy-is-trouncing-nuclear-93519