ARENA - ADVANCING RENEWABLES PROGRAM (ARP)

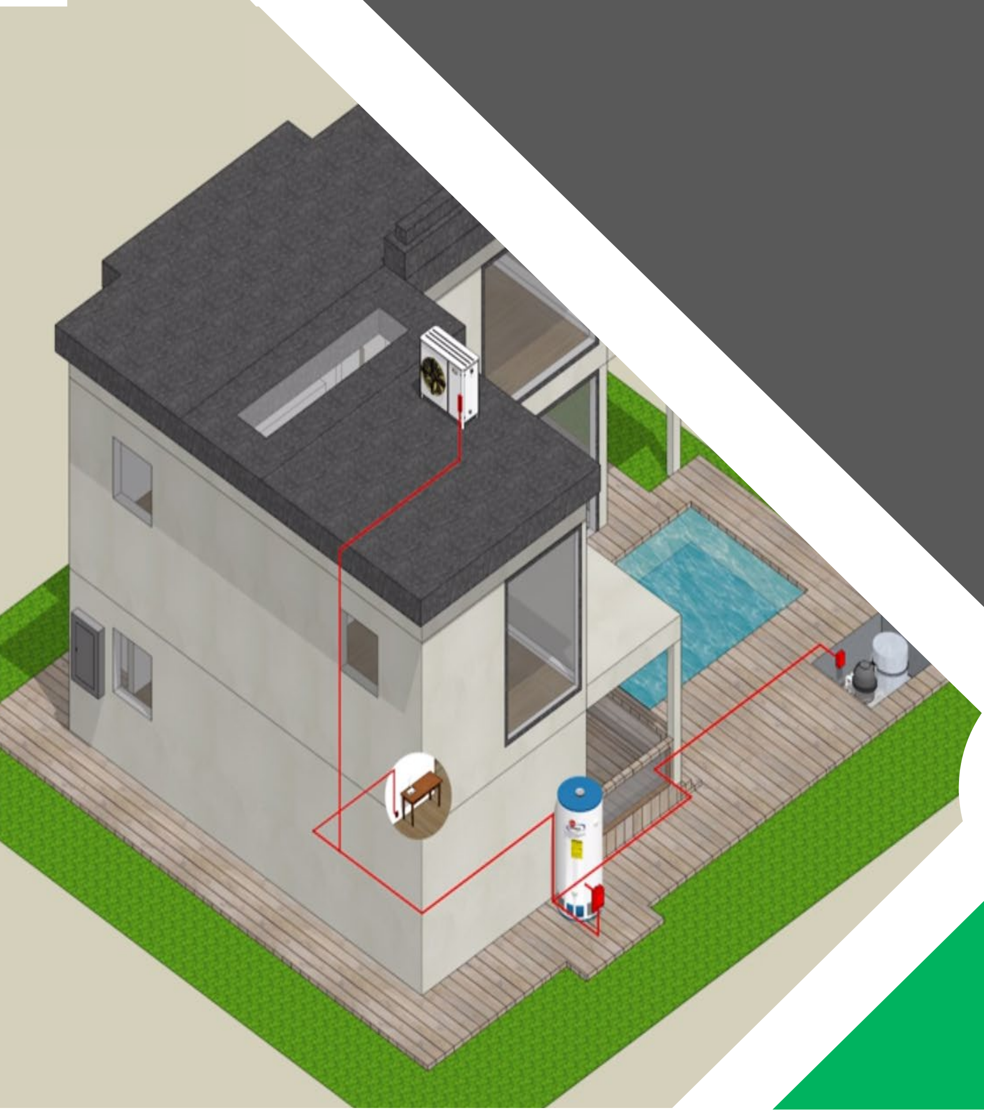
SOUTH AUSTRALIAN GOVERNMENT'S DEMAND MANAGEMENT TRIALS PROGRAM

SA SMART NETWORK Project

Knowledge Share Report

Bringing South Australia's Hot Water Load Under Active Control

May 2024



Rheem · Combined Energy · Simply energy by ENGIE · SA Power Networks · MARCHMENT HILL CONSULTING

Project Summary	
Project	Bringing SA Hot Water Load Under Active Control (SA Smart Network Project)
Project Numbers	ARENA: 2019ARP023 SA DEM: FA-00181
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Project Control	
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Date	**May 10, 2024**

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program and the South Australian Government's Demand Management Trials Program.

Acronyms

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
API	Application Programming Interface
ARENA	Australian Renewable Energy Agency
CET	Combined Energy Technologies
DER	Distributed Energy Resources
DNSP	Distribution Network Service Provider
DRSP	Demand Response Service Provider
FCAS	Frequency Control Ancillary Services
HWS	Hot Water Systems
HEMS	Home Energy Management System
kW	Kilowatt
kWh	Kilowatt Hour
MW	Megawatt
NEM	National Energy Market
PV	Photovoltaic
OPCL	Off Peak Controlled Load
SA	South Australia
SAPN	South Australia Power Networks
VPP	Virtual Power Plant

Contents

Executive Summary

The *Bringing South Australia's Hot Water Load Under Active Control Project*, also known as the SA Smart Network Project, which commenced in December 2019, was implemented by Rheem with support from the Australian Renewable Energy Agency (ARENA) and the Government of South Australia under its Demand Management Trials program. Combined Energy Technologies, SA Power Networks, and Project Retailers, Simply Energy and AGL also collaborated in the delivery of the project. The project sought to demonstrate that a fleet of actively controlled hot water systems can provide aggregated demand response within a Virtual Power Plant (VPP) to deliver potential wholesale and Frequency Control Ancillary Services (FCAS) value, network value along with savings to participating customers. It also sought to advance the commercialisation of a locally manufactured retrofit device to control hot water load.

This final Knowledge Share Report reviews the overall project to the point when it was halted, building on insights from previous Knowledge Share reports.

A key aspect of this report is its review of the final progress of the project across several factors including the technology used, commercial benefits, market benefits and the customer acquisition approach.

- Technical development – This section elaborates on the technology stack that was developed to support the final solution. The innovative nature of the project is highlighted with descriptions provided on the PowerStore Lite, Gateway Lite and inGrid VPP platform.
- Commercial/financial business case – This section seeks to demonstrate the commercial case for the PowerStore solution. Though the project closed early, significant data was captured and analysed for the potential benefits for participating customers, retailers, and the network. The analysis looked at the impacts of the smart hot water system on customer bills, assessing how the bill was impacted by change in the amount of energy exported to the grid, changes in amount self-consumed, shifting of grid usage to lower cost periods (as part of TOU plans) and other value opportunities. Several scenarios were modelling accounting for season variations and different size of Solar PV units and hot water systems.
- Regulatory and market findings – The project was halted early so limited insights were gathered related to its performance in the market. However, the project did successfully develop the software integration necessary to interface with SAPN and AEMO to participate in the wholesale energy and FCAS markets, It completed significant testing requirements for the participation of the smart electric water heaters enabled VPP in Behind the Meter (BTM) Distributed Energy Resources (DER) in the provision of Contingency Frequency Control Ancillary Services (FCAS) in compliance with AEMO's Market Ancillary Services Specification (MASS).
- Customer recruitment – Sales and marketing were a challenge for the project. The project recruited 92 customers onto the VPP, primarily Solar customers on the PowerStore Solar product. The Retrofit product was launched but uptake was limited. The section describes some of the challenges facing the project and how it responded.

This report also collates insights as directed by the funding authorities on the following topics:

- *Network Load coordination options for Hot Water (HW) load*. The PowerStore smart hot water system is controllable and enables Networks to harness load and engage in demand response, particularly in times of low demand and high Solar PV generation during the middle of the day. The project highlighted several benefits for Networks such as improving their ability to manage minimum demand, facilitating more renewables hosting particularly DER on the network and reducing peak demand.
- *Management options for the solar generation 'duck curve'*. Early insights from the installed based, showed how the PowerStore systems could be effectively deployed to manage the "duck curve'. The PowerStore devices for solar customers would heat the water during solar hours, using solar energy to heat water instead of grid electricity. The PowerStore with its larger storage tank of 315 litres compared to the traditional 250-litre tank, has greater capacity to soak up Solar PV energy. The system is also configured to heat the tank whenever solar energy is available, which meant that it would reheat during the day whenever the customer consumed hot water and solar energy was available.
- *NEM arbitrage strategies*. The project successfully developed the software integration necessary to interface with SAPN and AEMO to participate in the wholesale energy and FCAS markets, but it failed to recruit the minimum number of devices required to demonstrate VPP utility in the market. The system was able to visually represent a VPP in operation over an hour with energy flows captured every 5 seconds. It shows for a solar home, how PV is used for exports, in the home but also how it is used to heat the water system and when the water system is heated by the NEM.
- *Options to maximise behind the meter solar consumption*. Some sampling of the customer base was undertaken to understand the impact of smart hot water systems on consumption, particularly on self-consumption vs grid. Two sites were chosen for this analysis. Each site's consumption profile was then compared against two simulated baseline scenarios; Scenario 1 – customers are on an Off-Peak Controlled Load (OPCL); and Scenario 2: Uncontrolled hot water load. This analysis was run for both winter and summer. The analysis highlighted the value of using a PowerStore across different option scenarios.
- Retrofit vs PowerStore for wider roll-out of program. An early assessment was undertaken of smart hot water systems against 'retrofits', comparing functions such as smart technology, legionella control, tank temperature profile, etc. against solar-smart electric water heaters.

Despite the early closure of the project due to difficulties in customer acquisition, several key findings emerged through monitoring of the PowerStore and HEMS fleet in South Australia:

1. Energy for water heating represents 20% - 35% of the total energy demand from homes in South Australia, with peak percentage hot water demand aligning well with the worst months of minimum demand (the duck curve).
2. HEMS and an actively controlled, smart electric water heater use more BTM solar power for water heating, improve solar self-consumption and reduce

energy export than alternatives of water heating on OPCL or uncontrolled water heaters.

3. Peak export and peak demand are reduced through the use of HEMS and an actively controlled, smart electric water heater.
4. Wholesale market and network costs are reduced for retailers when HEMS and an actively controlled water heater are used by a household.
5. In the winter months, and under the current pricing mechanisms, OPCL is still the cheaper alternative (against uncontrolled water heaters or HEMS and smart electric water heaters) for consumers to heat water. Given the benefits to the network and to retailers, there is potential for redistribution of the costs and benefits to more fairly price actively controlled hot water for consumers.

This is the final Knowledge Share report of the project and provides an overview of activities and learnings at close. It explores the importance of the project, insofar as demonstrating how actively controlled hot water systems could be harnessed to provide aggregated demand response, and deliver a host of benefits to customers, the network, and the market. Unfortunately, the project was halted early but the learnings gathered are important and could provide value to other initiatives seeking to explore the opportunities associated with VPPs and the management of DER.

1 Project Overview

1.1 Project overview (context, objectives, outcomes achieved)

1.1.1 Project Context

Storage electric water heating is a significant electricity sink, ***comprising 25% of household energy use in Australia*** (the second largest segment of household energy consumption behind space heating and cooling). As a large energy-using appliance that can be “time shifted” due to the storage of energy in heated water, many DNSPs offer a controlled load tariff that is applied to electric water heaters during off-peak times (referred to as Off-Peak Controlled Load, OPCL), so that they can draw electricity at a predictable time and a cheaper rate. In South Australia, this load is set through static time switches to operate overnight between 11PM and 7AM, although more recently SAPN has added a Solar Sponge period between 10am and 3pm. Similar timings for OPCL exist across all NEM regions.

This off-peak timing is based on historic centralised generation, and transmission network loads which have become out-dated due to high penetrations of residential solar in the network. With growing rooftop PV penetrations, significant volumes of electricity are being generated such that grid demand during the middle of the day is being reduced to record low levels, creating the “duck curve” **(Figure 1**)[1]. In addition, PV uptake has increased variability in the range of power flows that the network must be able to support (i.e. demand transience due to cloud cover, fluctuations in demand between the middle of the day and in the late afternoon) and can cause power quality issues such as high voltages when PV systems are at peak output. This can limit the renewable energy hosting capacity of networks unless costly network solutions are employed (e.g. transformer taps, voltage regulators, load compensators) or customers are incentivised to shift load through energy storage or demand management incentives.

[1] AEMO, South Australian Electricity Report (November 2023), Figure 16. Sourced online February 27, 2024 at: https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2023/2023-south-australian-electricity-report.pdf?la=en

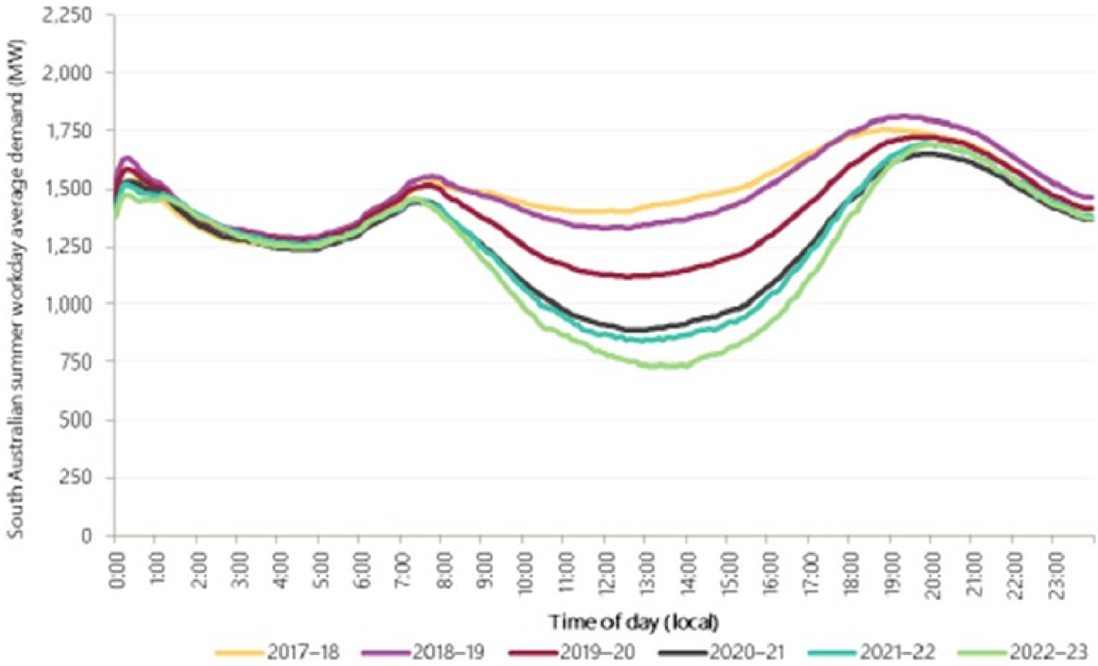

Figure 1 - Impact of Solar PV on Daily Demand Profiles in South Australia

SA Power Networks (SAPN) has over 300,000 off peak hot water storage loads throughout its distribution network. Assuming an average water heater power draw of 3.6 kW, this equates to 1080 MW of un-tapped DER load, with a total average daily energy consumption of between 3 – 4.5 GWh (based on 10 - 15 kWh of water heating per tank per day - weather and seasonally dependent). This represents a significant energy storage capacity across South Australia, and more widely the NEM, yet to be harnessed.

In South Australia, currently, these are switched on at a fixed time via mechanical time switches at the customers' premise, or in switches that have been incorporated through electronic meters. SAPN control over electric water heaters is limited to these time switches, which cannot be controlled dynamically or remotely, thus timing cannot be varied without manual adjustments for each customer. Furthermore, all hot water systems are currently run at their full load rating when heating, as a significant ramp rate which has previously driven spikes in electricity prices in SA.

Rheem's Smart Network project aims to bring this significant energy resource under control, using novel technology developed through 5 years of innovation in variable power water heating and home energy management systems. The project aims to test different strategies to shift the timing of water heating to consume excess solar PV generation during the day.

1.1.2 Summary of the project objectives

The SA Smart Network project aims to explore alternative approaches for shifting the timing of and demonstrating active control over hot water systems within South Australia.

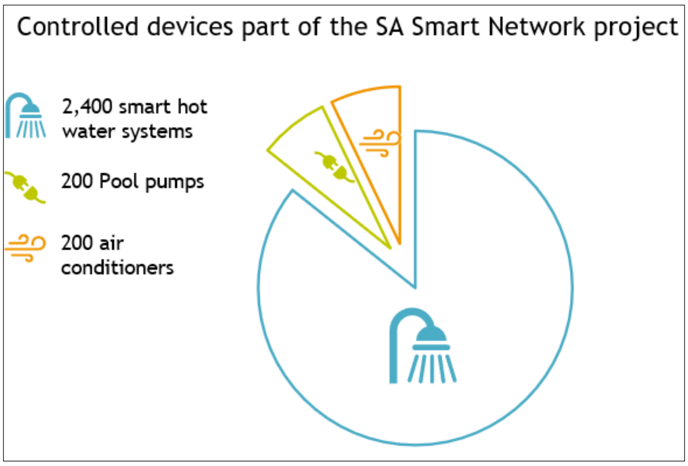

Figure 2: The initial device scope of the SA Smart network project

The project will explore the potential for 2,400 residential hot water systems along with (at a minimum) 200 air conditioning systems and 200 pool pumps to provide aggregated demand response within a Virtual Power Plant (VPP) to deliver wholesale market value to participating customers. The project will test the potential to derive further wholesale and deliver Frequency Control Ancillary Services (FCAS), in addition to bill optimisation for trial participants.

Furthermore, the project will investigate hot water control through testing a range of technologies and product offerings, developed to maximise participation from customers, assess customer preferences for participating in hot water demand management, and demonstrate a low-cost and scalable solution to providing active control. This will include the development and commercialisation of a locally manufactured retrofit device that can be added to existing hot water heaters.

The project also involves collaboration with CET, a leading provider of home energy management systems (HEMS) in providing active control over the hot water systems, SA Power Networks in developing a network tariff to incentivise hot water load shifting and a number of Project Retailers to develop a range of product offerings to achieve customer participation in the aggregation/orchestration of hot water systems within the VPP and to pass back value derived in the wholesale market to participating customers.

The Project will involve the development, deployment and demonstration of three solar-smart electric water heater solutions (PowerStore, PowerStore Lite and a Retrofit device) and two load control adapters, one for air conditioning systems and one for pool pumps. These devices will all be integrated with CET's HEMS. These products are described in the table below.

Technology	Quantity	Description
PowerStore	200 PowerStores in solar homes 200 PowerStores in non-solar homes	The PowerStore is a solar-smart electric water heater that was released by the Recipient to the market in Q3 2018. The PowerStore product can provide 15kWh of thermal energy storage and offers dynamic adjustments to its power demand on the network. The PowerStore will be available to customers who are replacing their hot water systems or to customers with new installations looking for a sophisticated and state-of the art HWS (with the benefits mentioned earlier).
PowerStore Lite	500 PowerStore Lites in solar homes 500 PowerStores Lites in non-solar homes	The Recipient is developing the PowerStore Lite that is designed to be a lower cost deployment solution to the PowerStore. It will not offer the full functionality of the PowerStore, however it will still offer active control. The PowerStore Lite will be available to customers who are replacing their hot water systems and customers with new installations.
Retrofit device	500 Retrofit devices in solar homes 500 Retrofit devices in non-solar homes	The Retrofit device will be developed to be retrofitted to existing hot water systems, targeting households that are not replacing their hot water systems. The devices will be low cost and allow for rapid deployment and will be available to solar and non-solar homes. The device will enable active control of existing hot water systems targeting customers with suitable water heater systems that are willing to upgrade to the new technologies to take advantage of savings and to assist with grid stabilisation.

Technology	Quantity	Description
Air Conditioning System Adapter	200	The air conditioning adapter will be developed to interface with existing air conditioning systems. These devices will be targeted at existing customers within the program to further increase the value of their solar smart electric water heater and Home Energy Management systems
Pool Pump Adapter	200	The pool pump adapter will be developed to function with pool pump systems. These devices will be targeted at existing customers within the program to further increase the value of their solar smart electric water heater and Home Energy Management systems
HEMS	The HEMS will be integrated with the PowerStore, PowerStore Lite, Retrofit, A/C Adapter and Pool Pump Adapter devices	CET's Home Energy Management System (HEMS) is the interface that enables active control of the hot water systems using Power Line Telecommunications (PLT) and to allow the CET/Rheem cloud-based application (Virtual Power Plant) to monitor and control household loads to shift the load into the solar period, to lower energy costs for consumers and to participate in stabilising the grid.

Table 1: Sales Plan for the SA Smart Network project.

1.1.3 Summary of the project outcomes

The project sought to demonstrate that hot water systems can provide aggregated demand response within a Virtual Power Plant (VPP) and deliver potential wholesale and Frequency Control Ancillary Services (FCAS) value to participating customers.

The objectives for the Project would be achieved through the following outcomes:

(a) improved understanding of the feasibility of different approaches for shifting hot water load to provide network value in SA, including the development of new tariff structures that reward electricity consumption aligned with variable renewable energy (VRE) generation;

(b) improved understanding of the incorporation of hot water load within a broader demand management package (through inclusion of other household controllable loads and/or DER types), as well as assessing customer preferences to different incentives;

(c) understanding the potential savings that solar and non-solar customers could receive to their electricity bills as a result of active control of hot water systems for load shifting and proposed new tariff structures;

(d) test the wholesale energy and FCAS value of aggregated hot water systems and other DER types as part of a VPP, with visibility for South Australian Power Networks (SAPN) and the Australian Energy Market Operator (AEMO); and

(e) advance the commercialisation of a locally manufactured retrofit device to control hot water load.

1.2 Purpose of this report

The purpose of this final Knowledge Share report is to document the outcomes, achievements, and lessons learned of the SA Smart Network Project. This is the final Knowledge Share report and serves to provide summary of what was achieved during the project, drawing upon insights and learnings from previous Knowledge Share reports. It explores the importance of the project, insofar as demonstrating how actively controlled hot water systems could be harnessed to provide aggregated demand response, and deliver a host of benefits to customers, the network and the market.

2 Update on Project Progress

This section of the report provides updates, learnings and insights garnered to date from the project on the following:

- Technical Development, operation, and performance (sub-section 2.1)
- Commercial and financial business case (sub-section 2.2)
- Regulatory and marketing finding (sub-section 2.3)
- Customer recruitment and participation (sub-section 2.4)

2.1 Technical development

The technology developed for the project consisted of a technology platform stack based on the following components.

- Customer DER - PowerStore and PowerStore Lite smart hot water system
- Hardware for detection and logging of frequency disturbance events ("FCAS events"), namely the CET-HD-PM2-1 Power Meter MASS-compliant FCAS meter
- Hardware and software systems for coordinating local response of site DER to FCAS events (CET-HD-EMU Energy Management Unit)
- Cloud systems and processes for automatic collection, time-alignment, post-processing and reporting of FCAS event data
- End user monitoring and configuration portal *atHome*
- Fleet management system for HEMS sites (*onWatch* Portal)
- Fleet management system for FCAS group management, configuration, monitoring and FCAS event reporting.
- InGrid Solution to facilitate operational management of the solution.

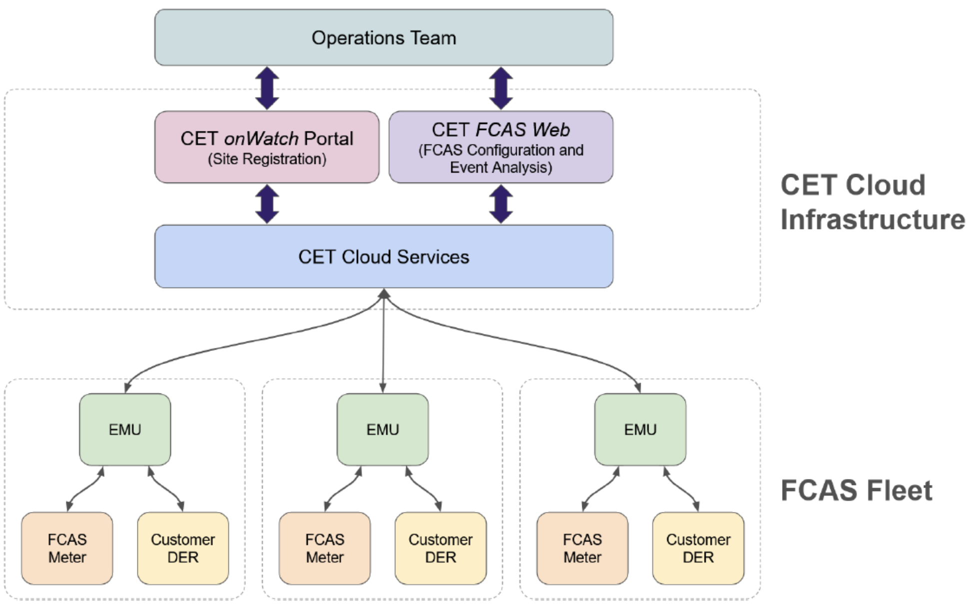

Figure 3: CET's FCAS Platform.

Technology	Description
Customer DER	• PowerStore smart hot water system. During the project, a PowerStore Lite product was developed as a lower cost alternative to PowerStore. PowerStore Lite is explored in section 2.2.1
FCAS Meter	• Hardware for detection and logging of frequency disturbance events ("FCAS events"), namely the CET-HD-PM2-1 Power Meter MASS-compliant FCAS meter • The CET-HD-PM2-1 Power Meter (PM2) provides up to 6 channels of CT-based circuit monitoring for single-phase and three-phase power systems and is used to monitor the site grid connection, generation and major loads of interest. In addition to the basic power/energy metering function, the PM2 implements a MASS-compliant 50ms FCAS meter and frequency trigger.
EMU	• The CET-HD-EMU-1 Energy Management Unit (EMU) is responsible for operating the local Home Energy Management System by coordinating customer DER to maximise solar self-consumption, minimise the cost of grid-supplied energy, and respond to FCAS events and other grid service requirements. • Upon detection of a departure of the grid frequency from the Normal Operating Frequency Band (NOFB), enabled Power Meters will commence logging of 50ms capture of the FCAS event and issue a high priority alarm signal to the EMU. Based on the system configuration and availability of local DER to respond, the EMU issues control signals to local DER to respond to the FCAS event. At this point, designated 'beacon' EMUs in the fleet transmit an alert to CET's Cloud Services to inform system operators of an ongoing FCAS event.
Cloud Services	In normal operation the load state of the site and status of customer DER is reported to CET's Cloud Services in a regular "heartbeat" message.
FCAS WEB	• The *FCAS Web* fleet management portal is used to manage the enablement and configuration of FCAS groups. • An FCAS group is a logical collection of NMIs (sites) under a label that reflects the group's geographical area (NEM region) and organisational association.
CET atHome Portal	Customer user interface for monitoring of system performance, energy consumption, costs and savings.
CET onWatch Portal	Management system for the registered HEMS sites
CET InGrid VPP Platform	The virtual power plant (VPP) platform called InGrid is used to control the South Australia fleet of Rheem PowerStore smart water heaters in response to demand response signals. The solution could be tailored to individual retailer requirements and captured such elements as the wholesale market price feed, network tariff etc.

	The inGrid platform enables the PowerStore smart water heaters to be controlled in aggregate in response to demand response signals.

Table 2: Explaining key elements of CET’s FCAS platform

2.1.1 Key innovations delivered by the project

Solution	Description
PowerStore Lite	Represented as the customer DER in Figure 2, the PowerStore Lite is the flexible, controlled load water heater with upper and lower heating element modules. It incorporates controller modules and associated circuits for control through power supply circuits.
Gateway Lite	Desktop controller for the Combined Energy home energy management systems.
InGrid VPP platform	InGrid is CET’s Virtual Power Plant (VPP) platform, that can be used to manage the aggregate fleet in response to market and demand response signals.

Table 3: A snapshot of innovations delivered by the project.

PowerStore

Figure 4: PowerStore.

A total of 92 PowerStore smart electric water heaters were installed, with 89 installed in solar homes and three in non-solar homes. All the PowerStore smart electric water heaters were connected to the EMU and the Home Energy Management System (HEMS), which controlled their operation. Additionally, Off-peak Controlled Load (OPCL) settings were programmed for the water heaters installed in non-solar homes, enabling the load to be shifted to the daytime, to take advantage of the Solar Sponge tariff.

PowerStore Lite

Figure 5: PowerStore Lite prototype.

PowerStore Lite was designed, prototyped, tested and certified. The PowerStore Lite was designed as a lower cost version of PowerStore. It uses seven stepped power levels in approximately 500W increments, rather than the more expensive step plus modulation method employed in PowerStore.

While the Office of the Technical Regulator provided an exemption for the use of 315L PowerStore and PowerStore Lite heaters for the project, the plumbing regulations in South Australia generally only permit up to 250L electric water heaters. Both 315L and 250L versions of PowerStore Lite have been developed with South Australia in mind.

Gateway Lite

During the project the 'Gateway Lite' Energy Management Unit (EMU), which is the desktop controller for the Combined Energy home energy management systems, was developed. The EMU is fundamental to realising the objective of home energy management ie to reduce the average price of power being purchased from the grid and to increase the use of solar in household appliances.

Figure 6: Gateway 'Lite' - Energy Management Unit.

Major electrical load, generation and storage devices in the home are coordinated by the EMU with reference to weather forecast data, energy prices and historical usage patterns in accordance with the energy management policies provided by the Combined Energy Cloud Platform.

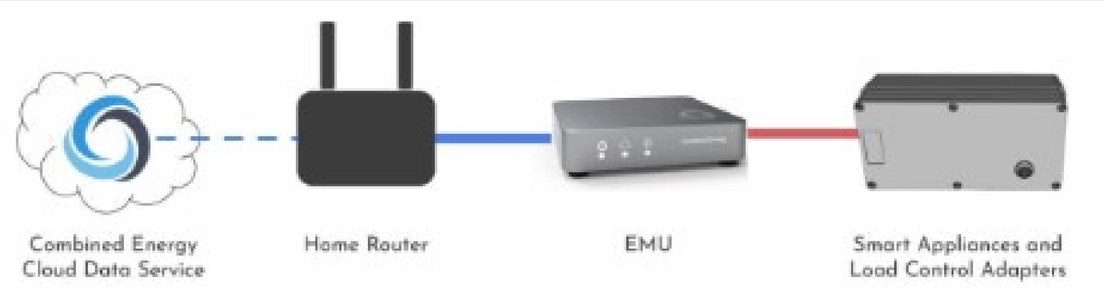

Figure 7: Linear architecture of the Energy Management system.

The EMU communicates with smart appliances ie PowerStore, and control devices within the home via Power Line Communications (PLC) using the existing building wiring.

The EMU connects to the Internet to download weather and tariff data, instructions and software updates and to upload site data via either the home network or a dedicated cellular connection. Direct connection to the local network is made by connecting an Ethernet cable to the home router, or by joining to the home Wi-Fi via and optional Wi-Fi USB dongle. The USB expansion port also supports a range of commodity USB cellular modems for standalone operation.

Historical energy consumption and cost data collected by the EMU from smart appliances and load control adapters in the home can be viewed on the Combined Energy atHome website ie the HEMS.

The atHome customer user interface with reactive views that adjust to all device screen sizes.

Figure 8: The atHome Live View user interface has been revamped to provide multiple views.

Figure 9: The atHome Live View provides a view where energy is being sourced & consumed.

The atHome Live View gives project participants a detailed breakdown of where energy is being sourced from and where it is being consumed. The interface has been updated to provide a range of communications including:

- Project-specific Messages
- “PowerStore Lite” Emulation
- NEM Wholesale Price Data Feed from the CET database
- Actual NEM spot price data and price forecast date is available to EMUs through a dedicated data service
- Additional “Top” Temperature Sensor for PowerStore 400 is being tracked in time series plots in the atHome interface

CET’s inGrid VPP platform

The inGrid VPP platform has been set up to manage and control in aggregate the fleet of smart water heaters installed. Further detail on aggregated fleet management is provided in ‘Attachment: D07i Evidence of Devices Under Control’, which provides details of a trial conducted to demonstrate the ability of a virtual power plant (VPP) platform, InGrid, to control the South Australia fleet of Rheem PowerStore smart water heaters in response to demand response signals. The demonstration aimed to provide concrete evidence for the Project regarding the potential of PowerStore smart water heaters to be controlled in aggregate in response to demand response signals from the VPP platform.

The inGrid VPP platform UI is tailored for each retailer. The following excerpts taken from the inGrid portal provide a view of wholesale market price feed and then of load on the network grid. These feeds are taken from the fleet managed by Simply Energy.

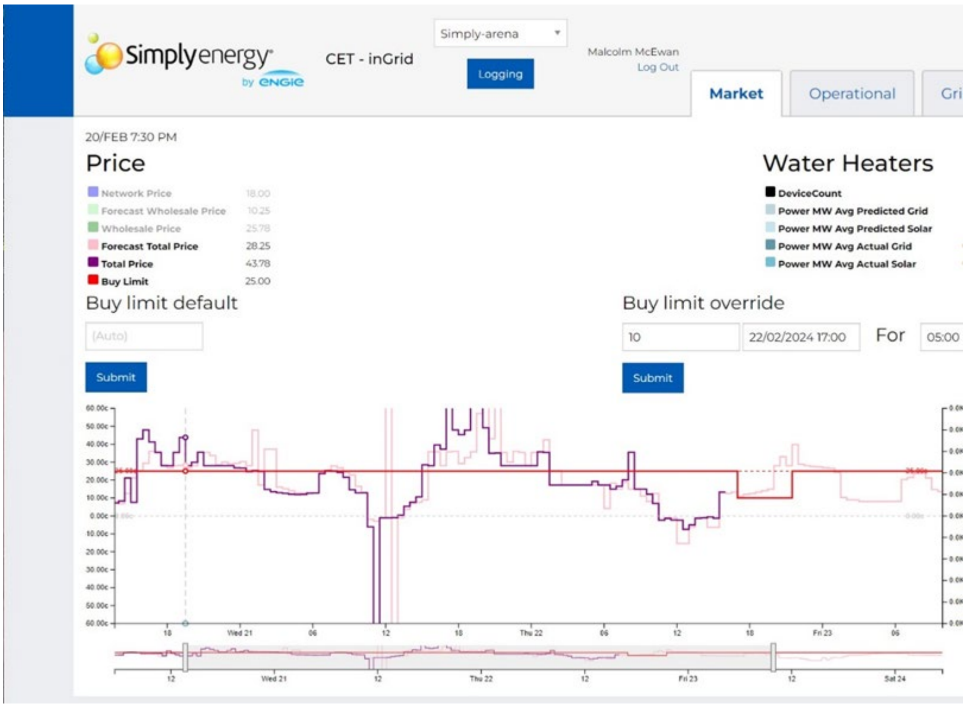

Figure 10: Snapshot from inGrid VPP platform providing view of wholesale pricing.

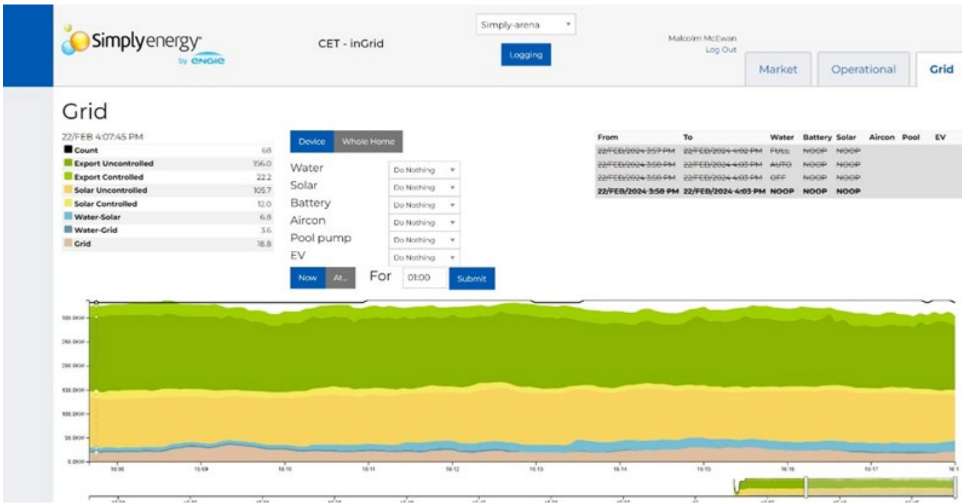

Figure 11: Snapshot from inGrid VPP platform providing view of demand and supply by type including DER.

Performance

A key outcome of the project was to understand the feasibility of different approaches for shifting hot water load to provide network value in SA, including the development of new tariff structures that reward electricity consumption aligned with variable renewable energy (VRE) generation. Even though the project failed to realise the proposed installed customer base before it was stopped, the project did generate some insights based on a baseline assessment of hot water load consumed by customers with electric resistive heaters on traditional off-peak controlled load (OPCL) tariff vs the smart water heaters.

This baseline load consumption was compared with that of a similar number of project solar/non-solar customers who were heating their water with smart water heaters. For solar customers, the CET Gateway Home Energy Management System (HEMS) provided control over the DER to optimise the consumer's solar PV self-consumption while for non- solar customers, the CET Gateway HEMS controlled the DER (hot water system) to maximise the absorption of excess PV generation in the surrounding low voltage distribution network.

2.2 Commercial/financial business case for customers

The project sought to demonstrate that a fleet of actively controlled hot water systems can provide aggregated demand response within a Virtual Power Plant (VPP) to deliver potential wholesale and Frequency Control Ancillary Services (FCAS) value, network value along with savings to participating customers.

Though the project closed early, significant data was captured and analysed for the potential benefits for participating customers, retailers and the network.

2.2.1 Approach to measurement

The analysis looked at the impacts of the smart hot water system on customer bills, assessing how the bill was impacted by:

- Changes in amount of energy exported to the grid;
- Changes in amount of energy self-consumed;
- Shifting of grid usage to lower cost periods on ToU plans; and
- Opportunity for further value to be realised

What each customer paid per day then was based on a factor of energy consumed from the grid by the tariff they paid.

The variable that was changed between each scenario was the ability to leverage Solar PV generated to heat the hot water system, either with active control or uncontrolled and based on the timing of hot water usage.

Benefits to the consumer, the retailer and to the network were all explored to identify opportunities to equitably re-distribute savings achievable along the supply chain to the benefit of the consumer.

Analysis was undertaken to understand the effect of the smart hot water system on energy consumption patterns and the monetary savings that occurred for customers, along with network benefits and savings for electricity retailers.

The installed fleet was categorised against the two parameters of volume of hot water used and the amount of solar generated from the home rooftop solar system. Small, medium and large for each parameter were determined using population quartiles of each measure. The first quartile being small, second and third quartiles medium and the fourth quartile was large. In approximate terms:

Hot water (measured using March data)

- Small - less than 5kWh of energy to heat water on average each day
- Medium – 5kWh to 11kWh
- Large – more than 11kWh per day

Solar PV (also in March)

- Small – less than 20kWh of solar energy generated on average per day
- Medium – 20kWh to 34kWh
- Large – more than 34kW per day

Sample sites with consistent behaviour were selected from five of the nine categories for detailed analysis. These sites are designated SHW-MPV, SHW-LPV, MHW-MPV, MHW-LPV and LHW-LPV. Each sample site had data extracted across the seasons to gauge weather related effects. Data was used from September, December, March and June. Each sample site in each season was modelled to understand the benefits of smart hot water systems under HEMS control against two simulated baselines. The baselines used are an electric water heater connected to the traditional 11pm to 7am OPCL circuit, and an uncontrolled electric hot water system connected to the general circuit of a household to enable use of the household Solar PV generation.

The variable that was changed between each scenario was the ability to leverage Solar PV generated to heat the hot water system, either with active control or uncontrolled and based on the timing of hot water usage. The uncontrolled water heater energy consumption profile is based on the AS/NZS 4234:2021 hourly thermal load model, as shown below.

7am	15%
8am	15%
11am	10%
1pm	10%
3pm	12.5%
4pm	12.5%
5pm	12.5%
6pm	12.5%

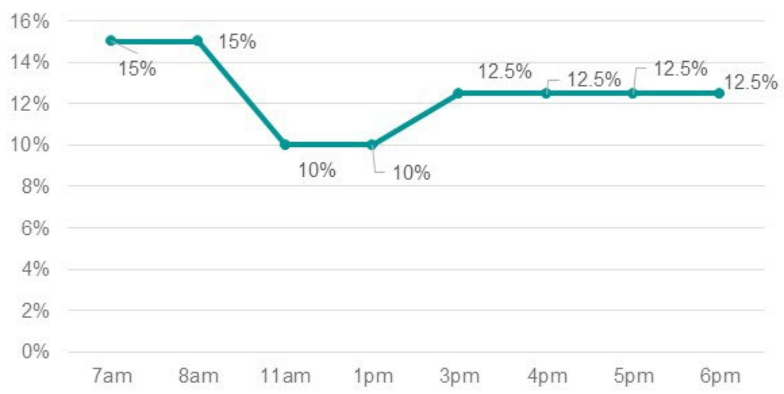

Figure 12: How energy is consumed in a household based on the AS/NZS 4234:2021 hourly thermal load model. Typically, on any given day most energy is consumed in the morning and the evening.

Standard electric water heaters switch on to full power (typically 3.6kW) when the thermostat senses a drop in temperature. This was modelled based on the total daily energy consumption for water heating, reset to the AS/NZS 4234:2021 thermal load profile, and allowing for the 3.6kW power rating.

Similarly, the OPCL profile was based on the actual total energy used for water heating (as measured by the HEMS) and based on heating at 3.6kW, starting at 11pm.

Site SHW-LPV:

- See Appendix B1 – Site analysis – category SHW-LPV for energy charts.
- All energy figures (kWh) and costs are per average day in that month.
- With a larger solar system, the HEMS is able to achieve high percentages of solar power contribution to the smart electric water heater – ranging 84% in winter to 99% in summer.
- Solar generation almost trebles in summer over winter, while energy for hot water almost doubles in winter over summer. This is partly because of the lower ambient inlet water temperature.
- The energy used to heat water ranges between 25% of all energy used in the home in warmer months, to 35% in colder weather.
- Consumer electricity bills (whole of home) are better for the HEMS solution than either baseline, all year around, although OPCL gets close in winter.
- The HEMS solution reduces peak grid demand all year around. This is possible because the smart electric water heater uses variable power to match available excess solar, rather than turning on and off at full power.
- Self-consumption of generated solar power is improved by the HEMS solution coupled with the PowerStore as controllable load device.
- Network and wholesale energy costs to the retailer are significantly reduced by the HEMS and PowerStore.

	HW Usage	PV System		HW kWh	Solar gen kWh	Total Home Energy kWh	HW of Home Energy %					
	Small	Large	September	9.6 kWh	34.9 kWh	26.9 kWh	35.7%					
			December	6.9 kWh	62.9 kWh	26.8 kWh	25.8%					
			March	5.2 kWh	44.2 kWh	19.1 kWh	27.2%					
			June	8.7 kWh	19.9 kWh	25.3 kWh	34.2%					
	September (Spring)			December (Summer)			March (Autumn)			June (Winter)		
Daily	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS
Export kWh	15.3 kWh	23.2 kWh	19.4 kWh	39.6 kWh	45.8 kWh	40.6 kWh	29.3 kWh	33.7 kWh	30.5 kWh	5.8 kWh	12.0 kWh	10.4 kWh
Self Consume %	56.1%	33.6%	44.3%	37.2%	27.2%	35.5%	33.7%	23.8%	31.1%	70.9%	39.4%	47.5%
HW from Solar kWh	8.7 kWh	0.0 kWh	2.6 kWh	6.9 kWh	0.0 kWh	4.5 kWh	5.1 kWh	0.0 kWh	3.0 kWh	7.3 kWh	0.0 kWh	0.8 kWh
HW from Solar %	91.2%	0.0%	26.8%	99.0%	0.0%	63.7%	98.9%	0.0%	58.0%	84.0%	0.0%	9.7%
Max Grid Demand kW	1.3 kW	4.1 kW	4.5 kW	0.6 kW	4.0 kW	3.3 kW	0.6 kW	4.0 kW	3.8 kW	2.8 kW	3.9 kW	6.2 kW
Max Export kW	3.0 kW	3.7 kW	3.7 kW	5.6 kW	5.9 kW	5.9 kW	5.2 kW	5.2 kW	5.1 kW	1.7 kW	2.5 kW	2.5 kW
Retailer Costs	$0.13	$1.47	$1.38	$0.01	$1.09	$1.01	$0.01	$0.84	$1.03	$0.23	$1.24	$2.24
Consumer Cost	$3.23	$3.81	$5.62	$0.07	$0.76	$0.89	$0.93	$1.31	$1.86	$5.70	$5.83	$8.40

Table 4: A profile of household SHW-LPV: Small Hot Water & Large Solar PV.

Site SHW-MPV:

- See Appendix B2 – Site analysis – category SHW-MPV for energy charts.
- Half of the solar generation of the large PV system.
- Significantly less hot water usage and overall household energy consumption.
- Energy for water heating accounts for around 35% of household energy consumption all year around – quite a different profile.
- Maintains a high (>90%) level of solar power for hot water all year around.
- Low self-consumption of solar power in summer.
- With the lower power consumption, savings for the consumer against OPCL are lower.
- Savings to the retailer are generally over 90%.
- Very low peak demand from the network under HEMS, with some evening demand in cooler weather.

	HW Usage	PV System		HW kWh	Solar gen kWh	Total Home Energy kWh	HW of Home Energy %					
	Small	Medium	September	6.2 kWh	17.9 kWh	16.9 kWh	36.5%					
			December	3.7 kWh	31.3 kWh	10.5 kWh	34.9%					
			March	3.4 kWh	23.2 kWh	9.9 kWh	34.0%					
			June	4.3 kWh	9.0 kWh	11.9 kWh	35.7%					
	September (Spring)			December (Summer)			March (Autumn)			June (Winter)		
Daily	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS
Export kWh	8.2 kWh	13.1 kWh	11.7 kWh	24.4 kWh	27.4 kWh	25.4 kWh	16.6 kWh	19.2 kWh	17.8 kWh	2.8 kWh	5.7 kWh	5.3 kWh
Self Consume %	54.0%	26.6%	6.2%	22.0%	12.3%	18.7%	28.5%	17.1%	23.1%	68.9%	36.7%	40.7%
HW from Solar kWh	5.8 kWh	0.0 kWh	0.9 kWh	3.6 kWh	0.0 kWh	1.8 kWh	3.2 kWh	0.0 kWh	1.4 kWh	3.9 kWh	0.0 kWh	0.3 kWh
HW from Solar %	94.0%	0.0%	15.1%	96.5%	0.0%	49.6%	95.7%	0.0%	40.5%	91.8%	0.0%	6.3%
Max Grid Demand kW	1.3 kW	4.3 kW	4.6 kW	0.6 kW	3.9 kW	3.7 kW	0.6 kW	3.9 kW	3.7 kW	0.9 kW	4.0 kW	4.3 kW
Max Export kW	1.5 kW	2.1 kW	2.1 kW	3.7 kW	3.8 kW	3.8 kW	2.9 kW	3.2 kW	3.2 kW	0.6 kW	1.3 kW	1.3 kW
Retailer Costs	$0.05	$0.97	$0.88	$0.02	$0.58	$0.51	$0.02	$0.59	$0.67	$0.06	$0.62	$1.16
Consumer Cost	$3.76	$3.93	$5.72	$1.11	$1.26	$1.87	$1.41	$1.63	$2.26	$3.29	$3.37	$4.85

Table 5: A profile of household SHW-MPV: Small Hot Water & Medium Solar PV.

Site MHW-MPV:

- See Appendix B3 – Site analysis – category MHW-MPV for energy charts.
- Slightly higher hot water consumption (8-10kWh) all year round. Makes up around 50% of all energy used.
- Solar energy self-consumption in winter is high at 92%, dropping solar energy contribution to hot water down to 68% compared to 95% for the rest of the year.
- This is the first example we see of OPCL offering a lower cost to the consumer in winter when more grid power is purchased.
- Across the year the cost advantage is still with the HEMS solution.
- One of the learnings is that sizing the PV Solar system to provide good coverage in winter optimises the benefits of HEMS.

	HW Usage	PV System		HW kWh	Solar gen kWh	Total Home Energy kWh	HW of Home Energy %					
	Medium	Medium	September	10.1 kWh	20.1 kWh	19.9 kWh	50.7%					
			December	8.0 kWh	40.1 kWh	17.3 kWh	46.4%					
			March	8.1 kWh	26.7 kWh	14.4 kWh	56.3%					
			June	8.9 kWh	9.8 kWh	20.8 kWh	42.7%					
	September (Spring)			December (Summer)			March (Autumn)			June (Winter)		
Daily	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS
Export kWh	6.4 kWh	14.7 kWh	12.0 kWh	27.1 kWh	34.5 kWh	29.1 kWh	15.8 kWh	23.6 kWh	19.5 kWh	0.8 kWh	5.0 kWh	4.2 kWh
Self Consume %	67.9%	27.0%	40.4%	32.4%	13.9%	27.4%	41.0%	11.7%	27.0%	92.2%	48.9%	56.8%
HW from Solar kWh	9.6 kWh	0.0 kWh	1.5 kWh	7.9 kWh	0.0 kWh	4.8 kWh	7.9 kWh	0.0 kWh	3.1 kWh	6.1 kWh	0.0 kWh	0.2 kWh
HW from Solar %	94.9%	0.0%	14.7%	98.3%	0.0%	60.0%	97.3%	0.0%	38.6%	68.4%	0.0%	1.7%
Max Grid Demand kW	0.8 kW	3.9 kW	4.3 kW	0.8 kW	4.2 kW	3.9 kW	0.6 kW	3.9 kW	4.0 kW	2.0 kW	4.0 kW	5.2 kW
Max Export kW	1.7 kW	2.7 kW	2.7 kW	3.9 kW	4.2 kW	4.2 kW	3.2 kW	3.7 kW	3.6 kW	0.1 kW	1.3 kW	1.3 kW
Retailer Costs	$0.04	$1.54	$1.46	$0.01	$1.25	$1.16	$0.02	$1.29	$1.59	$0.33	$1.27	$2.30
Consumer Cost	$3.51	$3.97	$6.19	$1.31	$1.97	$2.49	$1.73	$2.53	$3.45	$6.06	$5.43	$8.31

Table 6: A profile of household MHW-MPV: Medium Hot Water & Medium Solar PV.

Site MHW-LPV:

- See Appendix B4 – Site analysis – category MHW-LPV for energy charts.
- The smaller hot water usage maintains a high percentage of solar energy for water heating, even in winter at 85%.
- The Solar PV system is very efficient in summer with almost five times the generation of the winter months.
- The relatively low hot water usage, coupled with a larger PV system allows for a high amount of export, especially in summer.
- The high export and low amount of energy purchased from the grid for the two baselines brings the electricity bill cost of the HEMS solution and the OPCL very close together.
- It is a situation like this that highlights the opportunity to distribute some of the savings at the retailer level back to the consumer to incentivise the reduction in peak demand and a modest reduction in reverse flow.

	HW Usage	PV System		HW kWh	Solar gen kWh	Total Home Energy kWh	HW of Home Energy %					
	Medium	Large	September	6.4 kWh	27.1 kWh	20.0 kWh	31.9%					
			December	5.1 kWh	51.7 kWh	23.2 kWh	21.9%					
			March	5.0 kWh	35.4 kWh	16.6 kWh	30.2%					
			June	4.5 kWh	11.0 kWh	16.6 kWh	27.0%					
	September (Spring)			December (Summer)			March (Autumn)			June (Winter)		
Daily	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS
Export kWh	14.9 kWh	20.4 kWh	18.0 kWh	35.0 kWh	39.5 kWh	36.1 kWh	24.4 kWh	28.9 kWh	26.0 kWh	3.7 kWh	6.2 kWh	5.7 kWh
Self Consume %	44.9%	24.6%	33.4%	32.2%	23.7%	30.2%	31.2%	18.3%	26.7%	66.1%	43.9%	48.5%
HW from Solar kWh	6.0 kWh	0.0 kWh	1.9 kWh	5.0 kWh	0.0 kWh	3.3 kWh	4.9 kWh	0.0 kWh	2.7 kWh	3.9 kWh	0.0 kWh	0.4 kWh
HW from Solar %	93.6%	0.0%	29.8%	98.3%	0.0%	65.0%	97.9%	0.0%	54.6%	85.8%	0.0%	7.8%
Max Grid Demand kW	1.3 kW	4.0 kW	4.6 kW	1.0 kW	4.2 kW	4.0 kW	0.6 kW	4.1 kW	4.1 kW	1.1 kW	4.0 kW	4.1 kW
Max Export kW	3.3 kW	3.6 kW	3.6 kW	5.3 kW	5.4 kW	5.4 kW	4.6 kW	4.8 kW	4.8 kW	1.1 kW	1.6 kW	1.6 kW
Retailer Costs	$0.05	$1.00	$0.91	$0.01	$0.80	$0.71	$0.01	$0.81	$0.99	$0.11	$0.65	$1.22
Consumer Cost	$3.66	$3.66	$5.35	$1.77	$1.64	$2.52	$2.09	$2.12	$2.97	$4.89	$4.41	$6.26

Table 7: A profile of household MHW-LPV: Medium Hot Water & Large Solar PV.

Site LHW-LPV:

- See Appendix B5 – Site analysis – category LHW-LPV for energy charts.
- Moderately large hot water usage and Solar PV generation.
- The overall home is a high energy user with the cooler months seeing usage exceed generation.
- The evening peak demand is significant and drives higher daily costs for the consumer in the cooler months.
- With an average of only 30% of energy consumption being for water heating (which can be controlled), grid demand is relatively high.
- The ratio of savings from controlled water heating to the higher costs of grid power, along with recovery through export in the two baseline scenarios means that the OPCL comes in at a lower cost for the consumer.
- Network benefits are best from the HEMS and PowerStore with peak demand and export both reduced.
- Retailer costs to provide energy for water heating are almost eliminated in the months of high solar contribution to water heating. As the solar contribution dips to 83% in winter, a few extra cents of network tariffs and wholesale market costs creep in.

	HW Usage	PV System		HW kWh	Solar gen kWh	Total Home Energy kWh	HW of Home Energy %					
	Large	Large	September	8.9 kWh	28.8 kWh	32.0 kWh	27.9%					
			December	6.3 kWh	46.7 kWh	28.7 kWh	22.0%					
			March	7.0 kWh	35.0 kWh	22.4 kWh	31.1%					
			June	8.1 kWh	16.6 kWh	22.4 kWh	36.4%					
	September (Spring)			December (Summer)			March (Autumn)			June (Winter)		
Daily	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS	Smart Electric, HEMS	HWS on OPCL	Uncontrol HWS
Export kWh	12.1 kWh	17.4 kWh	15.0 kWh	26.0 kWh	28.4 kWh	25.1 kWh	18.1 kWh	23.9 kWh	20.4 kWh	3.1 kWh	7.3 kWh	6.4 kWh
Self Consume %	58.0%	39.4%	47.8%	44.2%	39.2%	46.3%	48.3%	31.7%	41.8%	81.2%	56.0%	61.3%
HW from Solar kWh	8.4 kWh	0.0 kWh	2.0 kWh	6.2 kWh	0.0 kWh	3.3 kWh	6.6 kWh	0.0 kWh	2.9 kWh	6.8 kWh	0.0 kWh	0.5 kWh
HW from Solar %	94.5%	0.0%	21.9%	97.9%	0.0%	52.3%	95.2%	0.0%	42.1%	83.4%	0.0%	5.6%
Max Grid Demand kW	2.1 kW	4.2 kW	5.2 kW	0.8 kW	3.9 kW	3.8 kW	0.7 kW	3.9 kW	4.2 kW	1.2 kW	3.9 kW	4.8 kW
Max Export kW	2.3 kW	3.6 kW	3.6 kW	4.5 kW	4.7 kW	4.7 kW	3.4 kW	3.7 kW	3.7 kW	1.1 kW	2.3 kW	2.3 kW
Retailer Costs	$0.04	$1.38	$1.29	$0.01	$0.99	$0.90	$0.05	$1.12	$1.37	$0.18	$1.18	$2.11
Consumer Cost	$6.68	$6.18	$9.22	$1.67	$2.11	$3.09	$2.28	$2.64	$3.65	$5.16	$4.98	$7.68

Table 8: A profile of household LHW-LPV: Large Hot Water & Large Solar PV.

2.2.2 Summary

In summary, customers using a PowerStore and HEMS system to heat their water benefit financially from lower energy costs compared to customers on an OPCL or with uncontrolled hot water load in summer, when Solar PV generation rates are higher. Some of these benefits are diluted particularly against OPCL in winter. However, this can be mitigated by further value sharing between the retailer/network and the customer. Tables 1A/2A highlights that there is an opportunity - due to reduced network costs/wholesale costs in the PowerStore scenario - to further reduce costs for those customers on a PowerStore smart hot water system. Also, Rheem has developed guidelines and frameworks around optimal sizing of Solar PV units and the smart hot water system. This serves to further enhance the benefits to be realised by the PowerStore solution against OPCL as well as customers with an uncontrolled load.

2.3 Regulatory and market findings

Another outcome proposed by the project was to test the wholesale energy and FCAS value of aggregated hot water systems and other DER types as part of a retailer VPP, with visibility for SAPN and the Australian Energy Market Operator (AEMO).

The project successfully developed the software integration necessary to interface with SAPN and AEMO to participate in the wholesale energy and FCAS markets, but it failed to recruit the minimum number of devices required to participate in AEMO's VPP Demonstration program.

To participate as a VPP, an aggregator is required to have 1MW of water heaters deployed in the NEM region. To achieve this with confidence in firm capacity, it is estimated that a minimum of 1,000 PowerStore water heaters need to be deployed in the SA Smart Network project. To date 93 were installed.

However, at close, the project has completed significant testing requirements for the participation of the smart electric water heaters enabled VPP in Behind the Meter (BTM) Distributed Energy Resources (DER) in the provision of Contingency Frequency Control Ancillary Services (FCAS) in compliance with AEMO's Market Ancillary Services Specification (MASS). To register a Distributed Energy Resource (DER) behind the meter (BTM) for Contingency FCAS requires that an "injection test" is performed on the device to characterise the droop curve / response of the device.

The injection test as specified by AEMO is a modification of the line frequency to ensure the device responds to the FCAS trigger points when frequency becomes too high or too low on the grid.

The above testing has 2 parts:

- Phase 1 - Lab Injection Testing of an individual device (e.g. the PowerStore water heater). This was completed.
- Phase 2 - Field testing of an aggregation of water heaters. In this test the aggregated power must be a minimum of 1MW. 1MW is the minimum aggregated BTM resource required to participate in contingency FCAS. Field Testing is used to demonstrate FCAS logging and alarm response to real-life Frequency Disturbance Events. Two parts of FCAS field testing and validation were planned as part of South Australia Smart Network (SASN) Project:

- **"Dry run" Field Testing** to demonstrate FCAS logging and alarm response to real-life. Frequency Disturbance Events (with load dispatch disabled) on a limited number of trial sites. This was completed.
- **FCAS Delivery Testing** to demonstrate live dispatch of customer DER with an expanded fleet of devices within the SASN fleet. *This part of testing was not conducted due to the early closure of the Project.*

2.4 Customer recruitment and participation

2.4.1 Participation

The project recruited 92 customers onto the VPP, primarily Solar customers on the PowerStore Solar product. The Retrofit product was launched but uptake was very poor.

Device	Type	Installed	Sales target
PowerStore	Solar	89	/ 200
	Non-solar	3	/ 200
PowerStore Lite	Solar		/ 500
	Non-solar		/ 500
Retrofit	Solar		/ 500
	Non-solar		/ 500
HVAC controller			/ 200
Pool pump controller			/ 200

Table 9: Volumes of installations by devices

2.4.2 Sales and Marketing Approach

The project struggled to onboard the requisite volume of customers. Sales and marketing was revamped with a number of changes made during the project including

1. Dedicated business development and direct sales staff were employed in South Australia to develop sales tools, recruit and train sales and installation partners and to support sales and installation activities.
2. Restructuring the Rheem Australia and Solahart sales teams in South Australia to enable the commitment of more senior sales management time to the project.
3. Specialist technical sales staff allocated to support the sales channel partners.
4. Significant sales and installation training of the original sales channel – the South Australian Solahart Dealers.
5. Expansion to include sales partners from the plumbing channel.
6. Dedicated trade events in the plumbing merchant channel.
7. The addition of non-Solahart solar industry sales partners.
8. Online by webinar (during COVID), then face to face training in sales and installation. Now also available as on-demand online training.
9. General PowerStore promotion.
10. Specific SA Smart Network promotion, including refinement based on engagement.
11. Preparation of Case Studies – three in total with one published.
12. Development and refinement of digital sales and marketing tools.
13. Addition of a specialist Marketing Product Manager experienced in the energy industry.

Other initiatives were also undertaken.

- Simplification of the contracting process at the point of sale
- Simplification of the rebate process
- Addition of a new retailer (AGL) who had a greater presence in the SA market

2.4.3 Barriers to Sales

Although Rheem anticipated challenges to selling smart electric water heaters due to the product's novelty as well as the trial element of participating in a VPP, the experience was more difficult than expected.

The project identified several specific barriers to customers' willingness to purchase and during the project enacted measures to mitigate their impacts.

Barriers	**Resolutions**
Requirement to switch retailers The purchase of a smart electric water heater and participation in the VPP required customers to change to a participating project retailer. This inertia to switch retailers is despite the compelling retail offer for program participants. This proved to be a significant barrier to customers' willingness to participate.	The project enrolled an additional retailer AGL, who had a larger market share in the SA market. This helped alleviate some of the issues around contracting with an energy retailer.
Requirement to switch to Time of Use retail plan Customers were required to move at least their PowerStore system onto a Time of Use retail plan, rather than flat rates (including OPCL) that they were used to. This often caused reluctance because of the perceived risk of higher costs.	Specific training for the customer facing sales teams around explaining that the HEMS would optimise around self-consumption of solar and then around electricity pricing if grid power was required.
Requirement to sign multiple contracts Customers were initially required to sign two separate contracts to be part of the trial - one with a participating project retailer for an eligible retail tariff and the other with Rheem/CET for participation in the virtual power plant and usage of the home energy management software. This was a source of hesitation and confusion for potential customers that did initially limit take-up.	Rheem initiated changes to the contracting process, streamlining the contractual process and simplifying the rebate process.
New Sales Channels The initial design of the project, assumed that much of the product sales would be through the Retail Energy channel partner, who was to actively promote PowerStore amongst its own customer cohort. The retail partner was to play the role of key acquisition partner and channel to market. They were also incentivised to participate in the project, by the opportunity to upsell or	Both markets operate slightly different. There are two distinct 'moments of truth' for customers in dealing with new hot water systems - those that buy when their current hot water system breaks down (breakdown market) and those who proactively upgrade their hot water system at other times (upgrade market) - and customers in these two markets display different purchasing behaviours.

sell new energy contracts to customers who purchased the PowerStore product (who were not part of their customer base). As the project progressed it became apparent that Energy Retailers were not best placed to drive demand and align to customer behaviours in the hot water breakdown market and new upgrade market.	The breakdown market is significant in terms of size, and we are observing that the behaviours of these customers is driven by time (to get hot water back ASAP) and price (as it is an unplanned household cost), both of which make it more challenging to offer them a higher priced and more complex product like a smart electric water heater as part of a VPP. The cost, perceived complexity of trial participation and novelty of the technology led to a longer sales cycle which is seemingly incompatible with the hot water breakdown market where customers are looking for an immediate replacement. In both cases, the channel to market via Retailers was viewed as not optimum and the project explored expanding its channel reach, particularly with regards the breakdown market through, • Opening new sales channels, particularly plumbing businesses • Improving communication and promotional materials surrounding the product and trial • Introducing additional electricity retailers to the project to reduce the number of perceived barriers to entry of the trial

Table 10: Barriers to sale

2.4.4 Role of Incentives

Rebates

The rebate structure was originally phased into two 'cash back' amounts, one on sign-up and a second paid after remaining in the program beyond August 31, 2022. It was shown that separating the rebates in this way did not create a sufficiently strong customer incentive to sign-up to the trial.

Rheem elected to switch the rebate structure to a single payment that is fully paid to customers upfront. This is simplifying the acquisition process particularly around the initial contracting of customers. This was positively received by customers and the channels to market.

Federal and state incentives that favoured heat pumps

The project was challenged to compete effectively with heat pumps that were favoured with rebates and incentives under energy efficiency schemes. Such schemes such as the Retailer Energy Productivity Scheme (REPS) in SA but also the Victorian Energy Upgrade (VEU) and Home Energy Efficiency Retrofits (HEER) in NSW had no categories that recognised and rewarded installations of smart hot water systems or smart connected water heaters. Households and businesses can receive free or discounted energy efficiency and energy productivity activities from energy retailers participating in such schemes. For example, activities include installing energy-efficient lighting, or water-efficient shower heads, or helping save energy for water heating. Heat pumps are also part of the REPS scheme in SA.

Under any scheme, the flexible, controlled load PowerStore water heaters were not eligible for significant credits and could not compete effectively with heat pump water heaters.

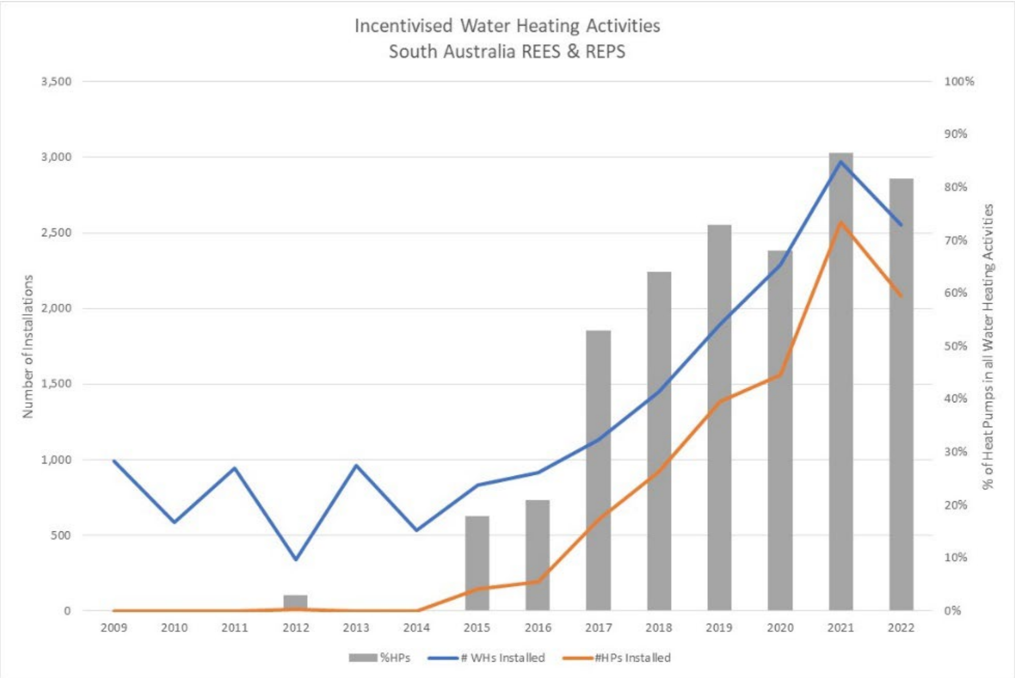

Figure 13: Growth in HPs installed 2019 -2022.

The project was initiated knowing that it would not be participating in the SA REPS scheme. However, it quickly became apparent that customers saw the PowerStore product as an equivalent to cheaper heat pumps that were part of the scheme, even though such products deliver significantly fewer consumer and grid benefits than the PowerStore product. The market for heat pumps grew dramatically during from 2019 through to 2022 as incentives began to fuel growth. Figure 10 explores how the market shifted dramatically during this period, just the PowerStore smart hot water system was launching.

As it became apparent that participation was an issue, the project suggested that an opportunity should have been explored to extend participation to the PowerStore product. The SA Smart Energy project is about delivering and acting upon learnings as it is about delivering commercial outcomes. Unfortunately, this was not achieved before project closure.

3 Insights from Network, Market and Customer report

The section of the report takes from previous Knowledge Share reports and provides an update on the following project themes:

- Reverse Power Flow problem
- Market and competitor analysis
- Customer Research
- An assessment of the Retrofit market

3.1 Reverse Power Flow problem

The electricity network was originally built to handle one-way flows of energy from large dispatchable power generators to the consumer. The network was designed for peak demands that are reduced, in aggregate, by natural diversity in customer usage patterns.

Today however, as customers continue to connect Distributed Energy Resources (DER) to SA Power Networks' distribution network at record rates (close to 50% of residential customers have rooftop PV systems), stress is created on the network by increasing two-way flows of energy and reverse flows (i.e. energy flowing into a grid at local nodes from DER installations). As a result, Solar PV eats up the state's operational demand particularly in the middle of the day. On Sept 16, 2023, according to AEMO, operational demand fell to just 21MW at 1:30pm, as residential Solar PV accounted for the rest of demand. This record was well below the minimum demand record set in October 2022 of 100MW and is the lowest operational demand a state has ever reached on the NEM.

This creates issues as when all rooftop PV systems in the same local area are exporting at full power simultaneously in the middle of the day, this increases the levels of daytime reverse power from the consumer back into the network. This is beginning to cause significant and widespread technical issues on the network.

These issues typically manifest on local LV areas first, but SAPN is beginning to see the impacts aggregated to higher levels of the network. As they become more widespread, negative customer impacts are increasing and SAPN is seeing:

- Continued escalation in the number of quality-of-supply enquiries from customers relating to PV driven overvoltage
- Increase in Ombudsman complaints relating to customer solar PV systems disconnecting from the network (caused by built-in safety features)
- Increasing expenditure on LV network remediation to resolve PV driven quality-of-supply issues
- Increasing PV penetration beginning to impact higher levels of the network
- Virtual Power Plant (VPP) performance impacted during periods of high solar output (referring to current programs in operation)

- Increasing concern from AEMO about operating the state under such high penetrations of unmanaged solar PV.

Managing Reverse Flows with Hot Water Systems (HWS)

Many initiatives are being investigated, trialled, and deployed to manage the local network and system level issues created by excess solar PV. One of these initiatives involves increasing daytime load to 'soak' up the excess solar. This method contributes to reducing issues presented at both local and system levels.

In South Australia more than 35% of residential customers heat their water using an off-peak controlled load register connected to their electricity meter. This resource is particularly attractive as an option to reduce excess solar because it is:

- already deployed in significant quantities;
- controllable or schedulable; and
- likely to be effective at reducing local issues as the resource is distributed in residential areas where the majority of distributed solar PV is installed.

How well 'matched' can scheduled hot water be to solar generation?

SA Power Networks analysed the shape of a typical existing hot water load profile arising from a number of systems in a local area under the current control regime, in which all systems start in the same hour with a 30-minute randomised start time and run at full power until they reach the target temperature set on the local thermostat. The following chart shows how this load would look if the start time was adjusted to begin at the start of the solar day and illustrates that the shape of this profile is not well correlated to the solar generation curve.

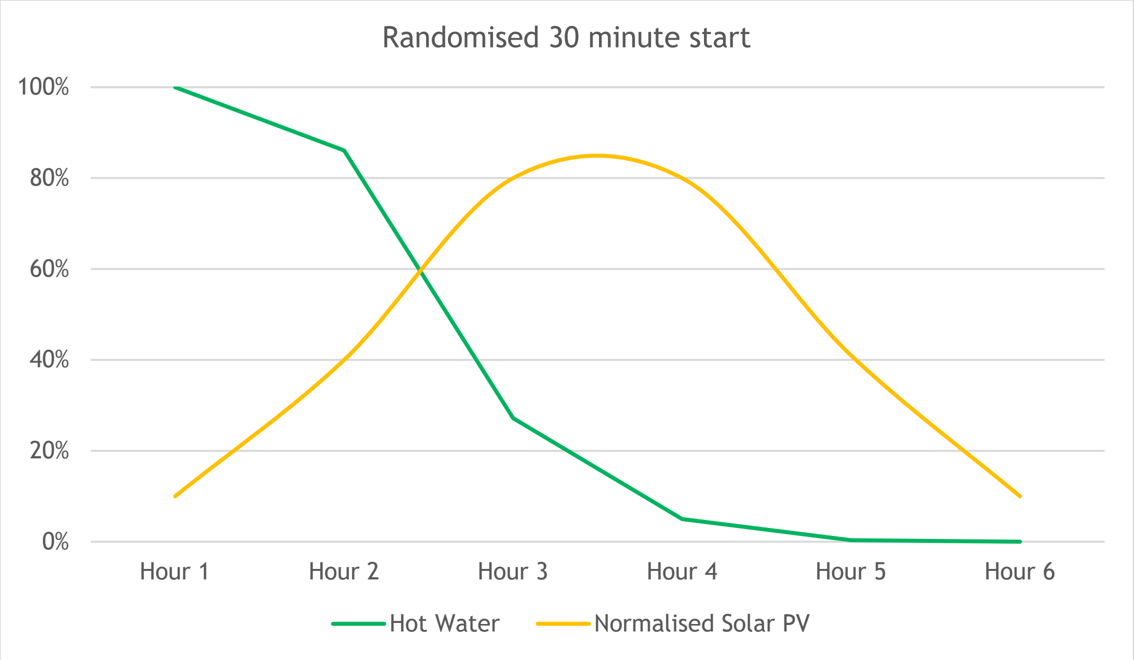

Figure 14: Matching Hot Water to normalised Solar PV over randomised 30-minute start.

With more sophisticated scheduling, it should be possible to better align the hot water load with solar generation. The figure below shows a theoretical profile in which start times are staggered to better match the solar generation curve. This profile was developed based on initial trials and assumptions that the smart hot water system can be programmed to react to increased supply of Solar PV during the middle of the day.

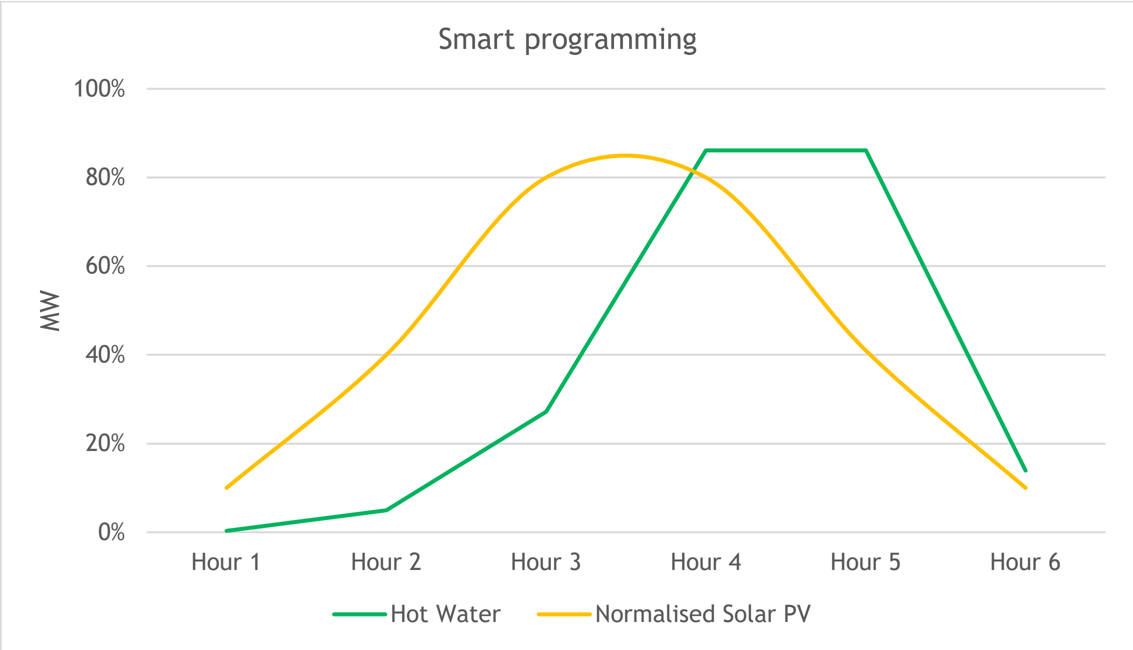

Figure 15: Matching Hot Water to normalised Solar PV with Smart Programming.

In practice, matching the hot water load curve with the solar generation curve in a particular region is more complex, partly because the solar curve can vary significantly based on average panel orientation, time of year and other factors. The two figures below demonstrate the difference in output of PV systems facing different directions and at different times of year.

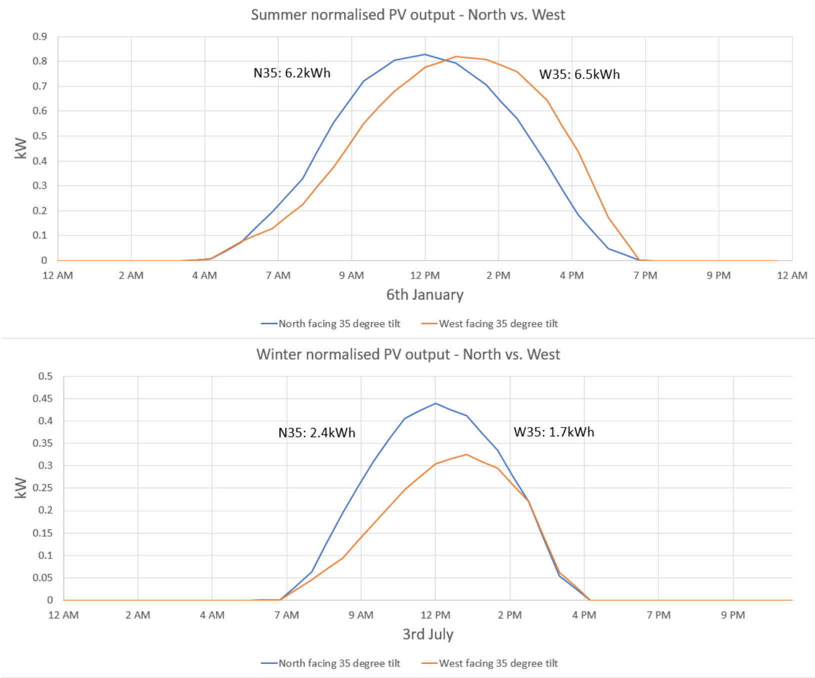

Figure 16: Regional and seasonal variations on the hot water load curve.

The hot water load curve also varies seasonally and by region, depending on the distribution of different water temperatures in customers' hot water systems at the start of the heating cycle. The practical outcomes of this trial seek to understand the best ways to match the two profiles.

What is the scale of schedulable hot water compared to solar generation?

Figures from AEMO suggest rooftop PV capacity in South Australia was 2,505 MW in 2022/23[2]. In comparison, we estimate there is approximately 1,080 MW (equating to 25% of typical household energy use) of electric hot water load in South Australia.

When considering the opportunity to use water heating to 'soak up' excess solar, it is important to consider not just the amount of load that can be shifted to the middle of the day, but also the amount of energy that can be absorbed. A typical 5kW rooftop PV system in SA will generate over 25kWh of energy on a spring day, whereas a typical 250L, 3.6kW hot water service may only consume around 10kWh in mild weather. In simple terms, 1kW of water heating will not have the storage capacity to fully absorb the output of 1kW of solar PV on a spring day. This means there should be particular focus put on making sure the controlled hot water is targeted at minimising peak generation through the middle part of the day, which will have the most impact on network and system stability issues.

[2] AEMO, South Australian Electricity Report (November 2023), p. 17. Sourced online February 27, 2024 at: https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2023/2023-south-australian-electricity-report.pdf?la=en

3.2 Market and competitor analysis

Analysis was undertaken to understand how a solar-smart electric water heater providing aggregated demand response within a Virtual Power Plant (VPP) could compete in the market. Because the market for smart, controllable and grid interactive water heating brings together both hot water heating and VPP participation, for the purpose of this analysis "the market" has been defined as comprising both:

- The market for **water heaters**
- The market for **VPP programs**

The competitive analysis following therefore considers these two markets in turn.

The market for water heaters

The competitive analysis on the potential solar-smart electric water heater solution (using Rheem's PowerStore as the basis) looked at a range of household factors:

- How much hot water is used
- The time of the day hot water is used
- The house size
- How many people live in the household
- The energy sources available in each location
- The tariffs that are available
- Whether solar PV panels are installed

The analysis highlighted that the market is not particularly competitive. The primary competitor products are technology-based companies offering add-on products (diverters, timers, etc.) or small-scale water heater manufacturers. Major water heater manufacturers to date, have not entered this market in any meaningful manner. This will likely change in the future.

The analysis highlights the strong competitive advantage of a solar-smart electric water heater solution currently around cost to run, technology and monitoring capability, noting the requirement for roof space to support Solar PV arrays. Details on the research and analysis are provided in a framework in Appendix A.

	Advantages	Disadvantages
Solar-Smart Electric Water Heater	Environmentally sound option to store excess energy from solar PV panels Able to monitor energy usage (CET) Lower running costs Easy to install Best use of excess solar PV energy compared to feed-in-tariff (FiT)	Requires roof space for solar PV Additional cost of solar PV Upfront cost
Solar Hot Water	Use free energy to heat water Less roof space than PV panels Low running costs Environmentally sound option	Not suited to frost or cyclone prone areas Direction and shaded area restrictions
Heat Pump Hot Water System	Small footprint Costs less to run than a standard electric Hot Water System Efficient	Poor performance in areas where climate can fall below 0°C (not an issue for most of SA) Noise may be an issue Slow to recover
Electric Hot Water	Lowest up-front cost Reliable with quicker heating and safety ratings (compared to gas)	Operating cost is typically higher than gas (though depends on usage and tariffs) Inefficient
Gas Hot Water	Ideal where there is limited sunlight or too cold for a heat pump	Higher up-front costs compared to electric Hot Water Systems
Instantaneous Hot Water	Ability to heat water only when it's needed No need for a storage tank so there is no heat loss from a tank which can reduce energy and save on energy costs Space-saving (no tank)	High cost for high volume users

	Advantages	Disadvantages
Power Diverter	Low cost Increases use of solar PV generation	Requires manual user intervention to boost heating on cloudy days Relies on an in-built timer to make “seasonal” assumptions to heat water along with a manual over-ride. Possible safety issues if not installed appropriately

Table 11: The Pros and Cons of some smart energy management solutions.

The market for VPP programs

We also undertook analysis of solar-smart electric water heater VPP programs in comparison to other VPP programs currently available. These are considered substitutes to solar-smart electric water heater VPP programs by providing alternative uses for excess solar energy.

The other VPP programs identified all involve using batteries to store excess energy, with the VPP operator tapping into the stored energy during periods of peak demand to supply the mains grid. A summary of battery based VPP programs is provided below[3].

	Compatible batteries	VPP participation incentive type	Eligibility requirements
Social Energy	Duracell "Energy Bank" or SolaX "Triple Power"	Feed-in tariff	NSW, QLD, SA, TAS, ACT
EnergyAustralia	Tesla Powerwall, Redback	Credit per grid event	EnergyAustralia customers
Members Energy	Eveready, Tesla Powerwall, Hive, AlphaESS	Feed-in rate during grid event	Energy Locals customers
Energy Locals / Tesla/ SA Gov.	Tesla Powerwall	Battery / solar installed free of charge	SA Housing Trust tenants
ShineHub / Powershop	Alpha-ESS	Battery subsidy	SA, VIC Powershop customers
AGL	LG Chem RESU "HV" or Tesla Powerwall 2	Battery subsidy + bill credit	NSW, QLD, SA and VIC AGL customers
Tesla Energy Plan	Tesla Powerwall	Battery subsidy	SA

[3] Data source: Solar Quotes. Accessed 28 January, 2021 at: https://www.solarquotes.com.au/battery-storage/vpp-comparison/

	Compatible batteries	VPP participation incentive type	Eligibility requirements
Origin	BYD B-Box HV	Battery subsidy + bill credit	VIC with min 5kW solar system
PowerClub	Sonnen	Bill credit	SA min 6kW solar system
Plico Energy	Pylontech	Battery subsidy	WA
Discover Energy	Battery that is compatible with Goodwe, Sungrow, SolarEdge or Alpha-ESS hybrid inverters	Feed-in tariff	NSW, SE QLD, SA
AusGrid	LG Chem, SolaX, BYD	Feed-in rate during grid event	On AusGrid networks and select Reposit Power, Evergen or ShineHub as DR provider
SonnenFlat	Sonnen	Annual energy allowance	Min. 3kW solar system and 4kWh battery

Table 12: VPP programs in place 2020.

Some of the advantages and disadvantages of battery-based VPP programs compared to solar-smart electric water heater VPP programs include:

	Advantages	Disadvantages
Battery-based VPP programs compared to solar-smart electric water heater VPP programs	Can provide energy backup in event of outage Provides energy for various household requirements (i.e. not just hot water)	Household participation in grid events possibly at times when battery support needed (e.g. during hot weather). Can induce voltage rise on the grid if grid voltage high at the time of discharge. Higher cost (before any incentives). Environmental issues with battery disposal.

Table 13: Pros and Cons of battery-based VPPs.

Pool Pump Control Adapters

Pool pumps and pump heaters are similar to water heaters in that they are non-disruptive controllable loads. The timing of electricity usage can be altered slightly without any inconvenience to the customer. They also draw large amounts of power. According to the Pool and Spa association, the average pool pump draws an average of 1.5kW when running and can consume 12-18 kWh/day. A pool heat pump can consume an additional 20kWh/day when running. As such, they are ideal devices for home energy management.

Air Conditioner Control Adapters

More than 90% of South Australian households have at least one air conditioner, with an additional 100,000 new air conditioners purchased in South Australia each year[4]. These come at a high cost (not only to air conditioning owners but also to other consumers on the electricity grid) due to both the amount of energy that air conditioners consume as well as the time at which they consume it.

In terms of total energy consumption, heating and cooling is estimated to account for 20% to 50% of total energy used in homes[5], figures which on their own would incur a significant cost increase. However, air conditioner usage also typically coincides with times of peak energy demand (i.e. during the morning and late afternoon or evening) which also adds network costs needed to support the additional peak load. The latter is not borne solely by the air conditioning owner but extends to other consumers on the electricity grid. For example for a 5kW air conditioner used during peak times, the AEMC estimates that the owner will pay additional network costs of $300 per year. However, a further $700 per year of network costs is also paid by other grid consumers who pay to support the additional peak load that the air conditioner creates[6].

The combination of high total energy consumption and usage typically coinciding with times of peak demand makes air conditioning a key target for home energy management. Combined Energy Technologies' control algorithm can reduce energy costs by moving air conditioning load from peak hours to off peak hours, as much as the customer will accept. By performing pre-cooling or pre-heating during the solar soak period or during the overnight off-peak period and keeping total operational time reasonably consistent, costs to operate air conditioning systems can be reduced for both the household as well as other grid users.

Unlike pool pumps and water heaters though, consumers are more likely to notice a change to their air conditioner operation if they are in the home when the change is made. To reduce this effect and customer dissatisfaction, the primary objective of air conditioner control will be to use algorithms that turn the air conditioner "on" pre-emptively when power prices are low (i.e.: when self-generated solar is available). The control algorithm will take consumer behaviour into account to anticipate when

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[4] SA Government. Accessed online March 31, 2021 at: https://www.sa.gov.au/topics/energy-and-environment/using-saving-energy/cooling

[5] Australian Government Department of Industry Science Energy and Resources. Accessed online March 31, 2021 at: https://www.energy.gov.au/households/heating-and-cooling

[6] Australian Energy Market Commission, "New rules proposed for distribution network prices" (2014). Accessed online March 31, 2021 at: https://www.aemc.gov.au/news-centre/media-releases/new-rules-proposed-for-distribution-network-prices

cooling or heating may be required and to potentially start that process before the customer initiates it, in order to take advantage of favourable price signals.

To mitigate the risk of customers continuing to run the air conditioning during peak times despite the control algorithm conducting pre-heating or pre-cooling during the off-peak times, the Home Energy Management System (HEMS) will provide notifications via the HEMS app reminding customers to reduce usage or to adjust thermostat set points during peak times. Behavioural responses to these notifications will be monitored with the possibility to also add functionality to automatically adjust thermostat set points during peak times.

3.3 Customer Research

Rheem with support from a research agency, Taverner Research, carried out 'Voice of the Customer' research on customers' attitudes to smart electric water heaters. This research was used to inform the initial application in 2019 and sought to better understand:

- Customer attitudes to hot water and hot water heating.
- Customer journeys with hot water.
- Customer understanding of energy and energy costs.
- Features that would offer benefit to customers, including grid-enabled water heating options tied to energy retail plans and credits.

Research was conducted via five, 2-hour focus group held with owners of Rheem electric storage water heaters. A total of 29 Rheem customers took part in the focus groups across the five sessions. The research was limited to Rheem customers in order to understand the views of customers who bought premium products, recognising that products in the solar-smart electric water heater space will be in a premium segment. Electric water heater customers were selected to ensure focus remained on electric water heater features – the most similar product to solar-smart electric water heaters.

All group participants shared the same characteristics (pre-selected in discussion with Rheem):

- Own their home outright or paying a mortgage.
- Live in a townhouse/duplex, semi-detached or free-standing home.
- Own a Rheem electric storage water system.
- Rheem storage system over 80 litres in size.
- Sole or joint decision maker in any water heater replacement decision.
- Mix of genders, ages and incomes.

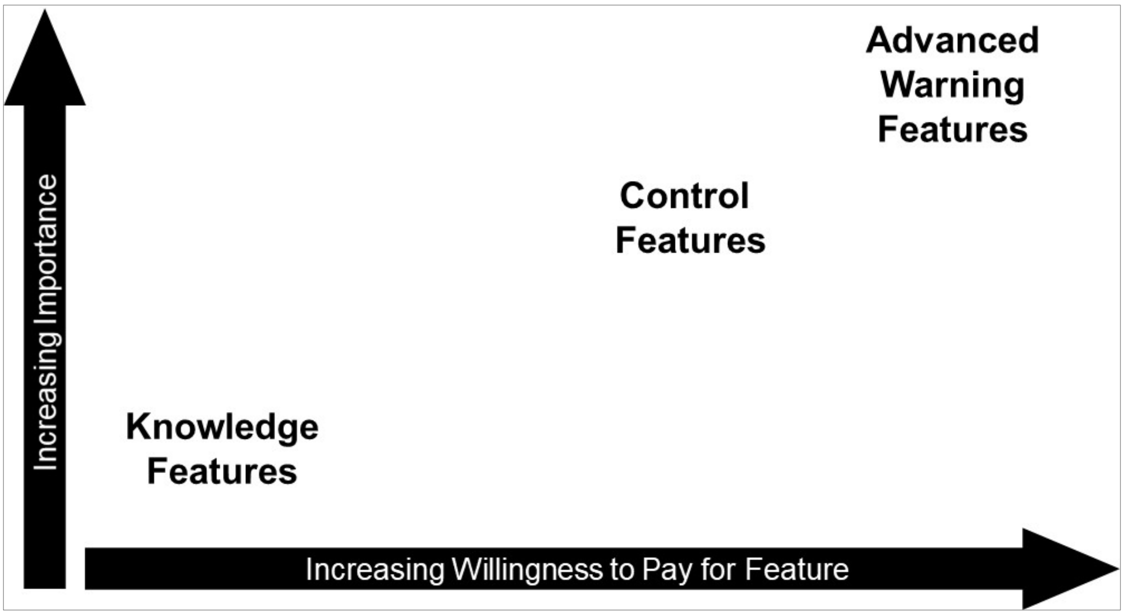
Taverner employed a 2-stage testing process to develop both a qualitative ranking of the features and elicit specific feedback about each feature:

Stage 1 – Group Ranking Exercise: The moderator showed each of the 22 potential features (not shared in this report due to commercial sensitivity) to group participants and had the group sort them into one of three piles: 'not important', 'important' and 'critical'.

Stage 2 – Group Discussion: Once the different features had been sorted, each of the features found in the 'important' and 'critical' were discussed as a group with a focus on 'why' each one was perceived as important/ critical, how they would use or benefit from the feature and whether they would be willing to pay for the feature.

Key Customer Attitudes Towards 'Smart' Features (Including External Control)

- Overall, the 'Advanced Warning Features[7]' were ranked the highest in terms of both importance and willingness to pay for them followed by the Control Features and the Knowledge Features (see Figure 17 below). A key control feature was the ability to access/control their 'Smart Water Heater' via an app on their phone was seen as a basic hygiene factor for almost all of the group participants.
- Consumers were open to paying a premium over and above the price of an existing 'non-smart' water heater in order to be able to access the advanced features of a 'smart' water heater.
- There was a need to develop an appropriate marketing and communications campaign, to change how consumers view water heaters – taking it from a low touch/low involvement appliance and elevating it to an essential amenity or an upgrade consumers will seek for their home.
- An outright purchase model was best as consumers indicated a dislike to the idea of handing over control of their appliances and data to third parties and were unlikely to take up leasing programs for a water heater.



[7] An early warning feature of the device that provides for advanced tank temperature sensing and powerline communications technology to allow intelligent home energy management.

Figure 17: Overall Ranking Results by Feature Group.

Implications for Development of the SA Smart Network Project

The learnings from the customer research influenced several features of the SA Smart Network Project, including:

Project feature	Reason
Outright purchase model	Consumers indicated they were unlikely to take up leasing programs for a water heater.
Proactively address concerns about handing over control of appliance and data to third party	Consumers indicated a dislike to the idea of handing over control of their appliances and data to third parties.
Focus on communication of Advanced Warning Features	These are the features ranked the highest in terms of both importance and willingness to pay.
Develop appropriate marketing and communications campaign to change how consumers view water heaters	To take water heaters from a low touch/low involvement appliance and elevate it to an essential amenity or an upgrade consumers will seek for their home.

Table 14: Elements of research that influenced the device design.

3.4 Assessment of Retrofit Solar Hot Water Systems

There are currently several makes of “solar diverters” or retrofits on the market. They are devices intended to be fitted in-line with the power supply to a conventional electric water heater, and their function is to throttle the power supply to the water heater to match available surplus solar PV power generation, thereby minimising power drawn from the grid. Further, some solar diverters can also change the power supply source to the water heater, in response to a change in tariff or other signalling.

Rheem assessed smart hot water systems against ‘retrofits’, comparing functions (highlighted in Appendix A) such as smart technology, legionella control, tank temperature profile, etc. against solar-smart electric water heaters.

4 Cost Benefit analysis

4.1 Network load coordination options for HW load

Water heating is a significant electricity sink, ***comprising 25% of household energy use in Australia*** (the second largest segment of household energy consumption behind space heating and cooling).

As a large energy-using appliance, if it can be harnessed effectively, it can be leveraged to manage load.

Traditionally, DNSPs offered customers a controlled load tariff (referred to as an Off-Peak Controlled Load, OPCL) to incentivise customers to use their heaters during periods when demand was low and supply higher. This was often at night (11pm to 7am). However, with growing rooftop PV penetrations, significant volumes of electricity are being generated such that grid demand during the middle of the day is being reduced to record low levels. This generation is less predictable than centralised generation.

The PowerStore smart hot water system is controllable and enables Networks to harness load and engage in demand response, particularly in times of low demand and high Solar PV generation during the middle of the day.

The PowerStore system provides active control over the water heater. It can focus on a particular time maybe 10am to 1pm during summer or over an extended period in winter. The system is set up to learn how the consumer uses its energy and monitors external sources such weather forecasts to ensure that hot water is always available in line with the configured times. It intelligently senses when excess solar power is available and uses it to heat water when needed. It uses two triple blade variable power input heating units designed to claw back any excess solar power available. It also has a large thermal energy storage capacity – around 13 kWh of thermal storage capacity is available for excess solar power capture.

In comparison, the most intelligent water heaters currently available, are switched on at a fixed time via mechanical time switches at the customers' premise, or in switches that have been incorporated through electronic meters. The DNSPs control over electric water heaters is limited to these time switches, which cannot be controlled dynamically or remotely, thus timing cannot be varied without manual adjustments for each customer.

The ability to provide for active control over the hot water load provides Networks several benefits:

Network Benefit type	Description
Management of minimum demand	'Time-shifts' consumption to times of minimum demand, when the there is a surfeit of Solar PV on the network. Networks must adapt infrastructure to manage minimum demand. This requires investment. The ability to provide for active control over the hot water load, is a lever that could be used to manage minimum demand issues.
Improves renewable energy hosting capacity of Networks	By using as much solar irradiation during times of minimum demand, customers are incentivised to continue investing in Solar PV.
Reduction in Peak Demand	By encouraging Solar PV expansion on the network and more self-consumption, spikes in peak demand are reduced. The network must invest in infrastructure to manage for peak demand events that may occur only 3 or 4 times a year. Further expansion of the Solar PV fleet coupled with a greater self-consumption of this energy (enabled by smart hot water systems) can impact peak demand events.

Table 15: Overview of network benefits.

Further network benefits were to be explored with a larger fleet before the project was concluded early.

4.2 Management options of the solar generation 'duck curve'

With growing rooftop PV penetrations, significant volumes of electricity are being generated such that grid demand during the middle of the day is being reduced to record low levels, creating the "duck curve". In addition, PV uptake has increased variability in the range of power flows that the network must be able to support (i.e. demand transience due to cloud cover, fluctuations in demand between the middle of the day and in the late afternoon) and can cause power quality issues such as high voltages when PV systems are at peak output. This in turn can limit the renewable energy hosting capacity of networks unless costly network solutions are employed (e.g. transformer taps, voltage regulators, load compensators) or customers are incentivised to shift load through energy storage or demand management incentives.

When considering the opportunity to use water heating to 'soak up' excess solar, it is important to consider not just the amount of load that can be shifted to the middle of the day, but also the amount of energy that can be absorbed. A typical 5kW rooftop PV system in SA will generate over 25kWh of energy on a spring day, whereas a typical 3.6kW hot water service may only consume around 10kWh in mild weather. In simple terms, 1kW of water heating will not have the storage capacity to fully absorb the output of 1kW of solar PV on a spring day. This means there should be particular focus put on making sure the controlled hot water is targeted at minimising peak generation through the middle part of the day, which will have the most impact on network and system stability issues.

Early insights from the installed based, showed how the PowerStore systems could be effectively deployed to manage the "duck curve'.

- The system is configured to act as a solar soaker, using excess energy produced during the day to heat water. The PowerStore devices for solar customers would heat the water during solar hours, using solar energy to heat water instead of grid electricity.
- The PowerStore with its larger storage tank of 315 litres compared to the traditional 250-litre tank, has greater capacity to soak up Solar PV energy.
- It is also configured to heat the tank whenever solar energy is available, which meant that it would reheat during the day whenever the customer consumed hot water and solar energy was available.

4.2.1 Approach to analysis

Early analysis of the installed base took a snapshot of usage (over a given month, June), comparing customers on a smart hot water system against simulations of customers on an OPCL or with uncontrolled water heating load. In Figure 18, the profile of this customer base on a OPCL is represented. Hot water systems are heated at night taking advantage of off-peak tariffs. During the day the 'duck curve' (as represented by the bold red line), is present with large volumes of Solar PV being generated in the middle of the day with minimum demand on the network. As noted, this scenario creates resilience issues for networks, struggling to deal with reverse flows.

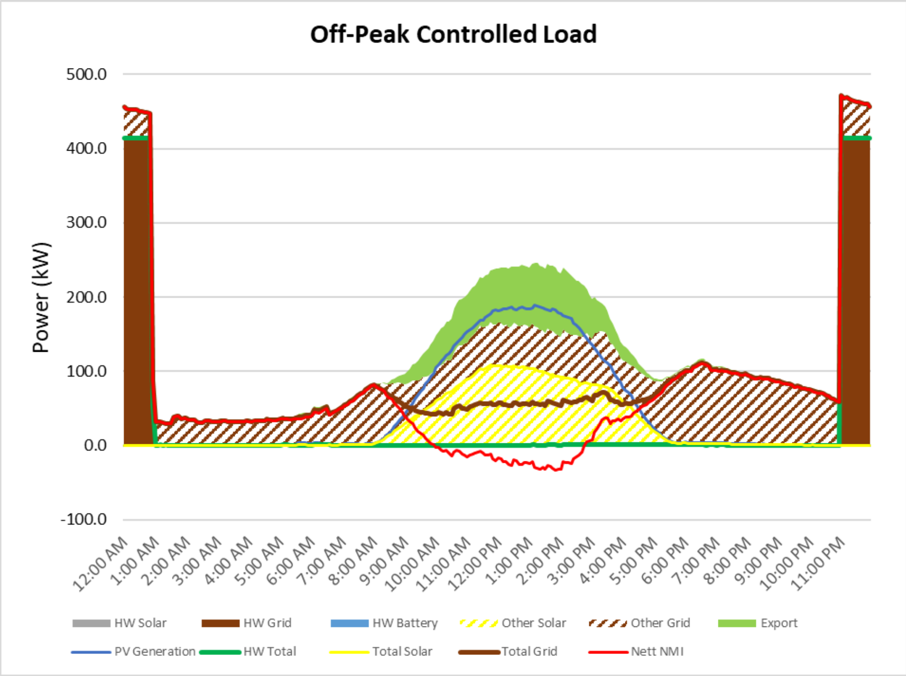


Figure 18: Profile of customers on an OPCL. Water tends to be heated at night taking advantage of low off-peak tariffs.

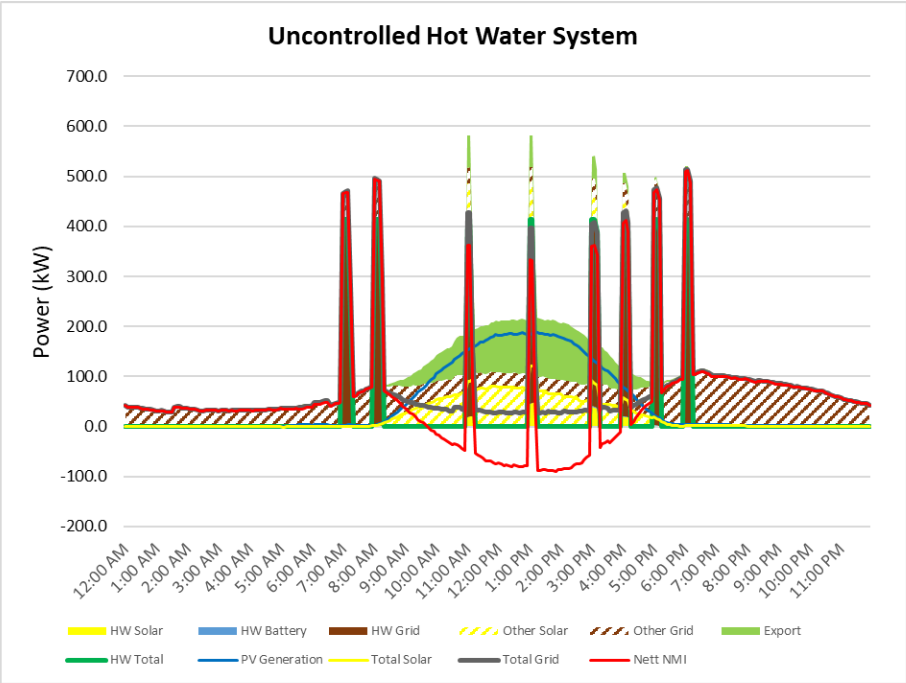


Figure 19: Profile of customers on an uncontrolled load. Water tends to be heated when required. It doesn't mirror Solar PV production well. Any use of solar power to heat water is coincidental rather than managed.

In Figure 19, the profile of this customer base on an uncontrolled load is represented. Hot water systems are heated during the day as required. During the day, the 'duck curve' (as represented by the bold red line), is present with large volumes of Solar PV being generated in the middle of the day with minimum demand on the network. The pattern is more chaotic, with some periods of energy usage with spikes in demand. However, the broad duck curve remains.

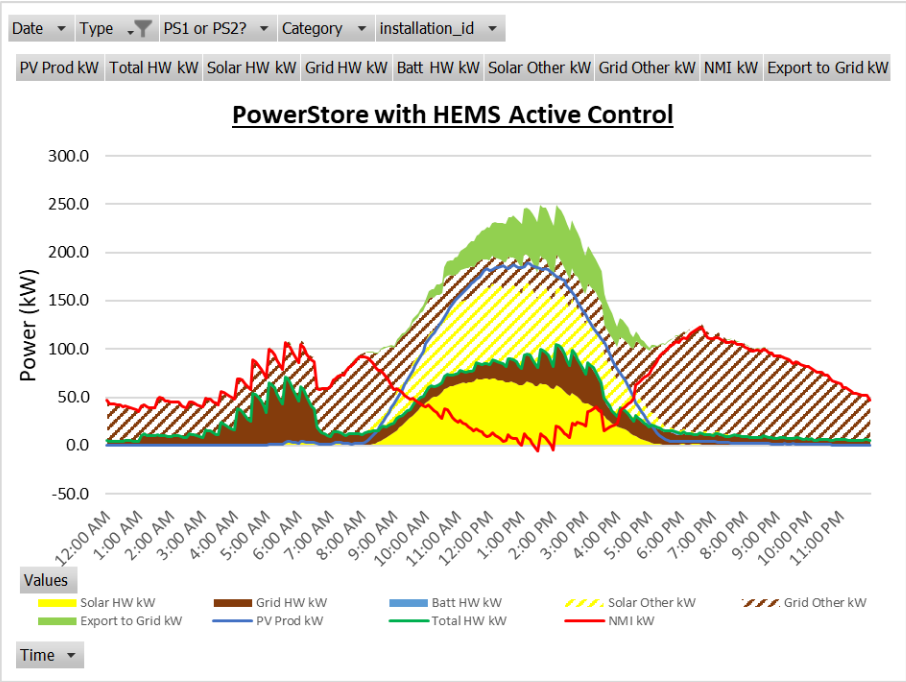


Figure 20: Profile of customers with a PowerStore system. Water is heated throughout the day, taking advantage of available Solar PV and when there is also capacity for more energy storage in the tank. This is a winter profile.

In Figure 20, the profiles of customers on smart hot water systems are shown. This is an average profile over a given month in winter. One can see that water is heated during periods of high Solar PV generation. Solar PV generated mirrors energy used to heat hot water systems. In this scenario, the duck curve is diminished with negative demand almost completely mitigated.

This early analysis shows that a smart hot water system can be an effective mechanism in reducing reverse flows particularly during the periods of the day when there is minimum demand. This reduces pressure on the network and improves resilience.

4.3 NEM arbitrage strategies

The project sought to showcase the advantage of selling excess energy back to the NEM as well as participation in the FCAS market. The Solahart PowerStore® was primarily marketed as an electric smart water heater (ESWH) that enabled customers to capture and utilise excess solar energy generated by their PV system to heat water in their household.

The project proposed to demonstrate the energy demand flexibility of an aggregated fleet of smart electric water heaters and other DER by forming a Virtual Power Plant (VPP) that would participate in the electricity wholesale and Frequency Control Ancillary Services (FCAS) markets. By participating in these markets, the VPP could capture value and provide incentives for customers whose DER assets participated in the network demand management events.

The project successfully developed the software integration necessary to interface with SAPN and AEMO to participate in the wholesale energy and FCAS markets, but it failed to recruit the minimum number of devices required to demonstrate VPP utility in the market. Figure 21 shows the VPP in operation over an hour with energy flows captured every 5 seconds. It shows for a solar home, how PV is used for exports, in the home but also how it is used to heat the water system and when the water system is heated by the NEM.

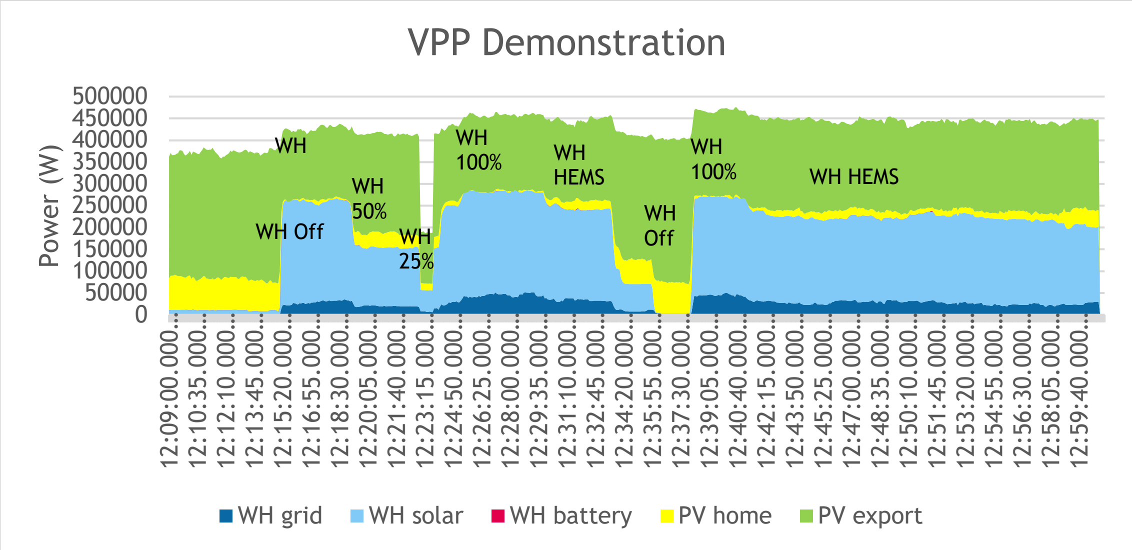


Figure 21: SA VPP demo - 5 second reads.

To participate as a VPP, Rheem is required to have 1MW of water heaters deployed in SA. To achieve this, an absolute minimum of 278 PowerStore water heaters need to be deployed in the SA Smart Network project. The charging state of individual water heaters means that we will need many more heaters to ensure the required 1MW capacity. Once deployed, AEMO can carry out post event verification, and the VPP is required to keep data for 5 seconds prior and 60 seconds post the event. If the requested verification data does not meet the AEMO standards, then fines may be levied on our VPP. Given that water heater switching response times (unlike batteries) are consistent, i.e. not affected by environmental changes (temp), charge state, line voltage and other conditions that affect a battery response time, (and hence the injection test droop results), we may find that less water heaters are required to meet the stringent certification than batteries.

This essentially means that Part 1 testing was able to be conducted with confirmation of software readiness from CET. Parts of Part 2 testing were put on hold since it is dependent on the deployment of a specific minimum number of PowerStores into the SA Smart Network.

4.4 Options to maximise BTM solar consumption

The PowerStore was primarily marketed as an electric smart water heater (ESWH) that enabled customers to capture and utilise excess solar energy generated by their PV system to heat water for their household.

The product provided Solar customers with several options to manage their behind the meter solar consumption, which ultimately contributed to reduced reliance on grid electricity resulting in lower energy bills.

- Customers were able to use more of the Solar energy produced by their PV systems in the home during times of peak generation. During these periods, less was exported, with more energy used to heat the water system. With water heated at times when energy was produced, there was also less reliance on grid electricity particularly during the summer.
- The provision of the larger PowerStore tanks, multiplied this effect. The PowerStore also had a larger storage tank of 315 litres compared to the traditional 250-litre tank, ensuring that customers continued to have at least 315 litres of hot water during the day.
- Customers were less impacted by export curtailments enacted by SAPN due to the fact the PV system was exporting less back to the network and instead using excess energy to heat their water systems.
- The PowerStore is also configured with the intelligence to heat the tank whenever solar energy is available, which meant that it would reheat during the day whenever the customer consumed hot water and solar energy was available. This resulted in both solar and non-solar customers benefiting from having a larger PowerStore tank.
- Customers could use the HEMS portal to monitor their energy consumption at home, track their solar energy savings, and access valuable information about their water heater. The information could enable them to adapt their consumption to exploit PV generation during the day.
- Non-solar customers were able to avail of a cheaper Solar Sponge electricity tariff which is 25% of nominal network electricity tariff to heat their water system during the day. Traditionally, customers had their electric water heaters connected to an off-peak network pricing between 1am and 6am, which was only 50% of the peak electricity network tariff. This meant that customers could only charge their water heaters at night, leaving them with only 250 litres of hot water available to last through the day. This meant that customers on a night OPCL had only 250 litres of hot water available to last them through the day. However, by configuring non-solar customers' electric water heaters to Off-Peak Controlled Load (OPCL) to daytime, they were able to access the cheaper Solar Sponge tariff, which is only 25% of the peak network electricity tariff - this enables them to tap into tariffs that are 25% cheaper than the normal peak tariff.

4.4.1 Measuring behind the meter solar consumption

Some sampling of the customer base was undertaken to understand the impact of smart hot water systems on consumption, particularly on self-consumption vs grid. Two sites were chosen for this analysis. A large site A, with a large hot water usage and a small to medium Solar PV system and a relatively smaller site B with less hot water usage and a large Solar PV system. Each site's consumption profile was then compared against two simulated baseline scenarios; Scenario 1 – customers are on an Off-Peak Controlled Load (OPCL); and Scenario 2: Uncontrolled hot water load. This analysis was run for both winter and summer.

Sample	Season	Energy used by site	Energy produced by Solar PV	Solar self-consumption	Solar exported	% of all Solar PV produced exported	Solar used by HW	% of HW from Solar PV
PowerStore HEMS	Winter	42.39kWh	7.69kWh	7.86kWh	0.01kWh	0.1%	5.5kWh	30%
OPCL	Winter	42.39kWh	7.69kWh	2.18kWh	5.51kWh	71.6%	0	0
Uncontrolled Load	Winter	42.39kWh	7.69kWh	2.18kWh	5.51kWh	71.6%	0	0
PowerStore HEMS	Summer	20.37kWh	17.72kWh	11.90kWh	5.81kWh	32.8%	8.36kWh	97.7%
OPCL	Summer	20.37kWh	17.72kWh	3.55kWh	14.17kWh	80%	0	0
Uncontrolled Load	Summer	20.37kWh	17.72kWh	5.58kWh	12.14kWh	68.5%	2.03kWh	23.8%

Table 16: Describes the energy use on a site (A) with a small to medium PV system but high hot water usage on a typical day in June and December.

4.4.2 Analysing Site A

Table 16 describes the consumption profile of the site A. Site A typically needs 42.39kWh of energy per day in June. It produces 7.69kWh of Solar PV. In the PowerStore scenario, 7.68kWh of Solar PV is used to heat the system or 30% of the energy required. There are almost no exports to the grid. Self-consumption is maximised and reverse-flows on the network are minimised. In comparison, in the OPCL and uncontrolled load scenarios, Solar PV is still exported. No Solar PV is used for heating the water system. In both these instances, customers would have to source extra energy from the grid, while the benefits of exporting (due to the low FiT) are minimised. Self-consumption is not maximised. Also reverse-flow on the network still needs to be managed.

In December, Site A needs 20.37kWh of electricity. It is now producing 17.72kWh per day. In the PowerStore scenario, the hot water system is using 8.38kWh of Solar PV produced meeting 97.7% of its needs. The site overall is consuming 67.2% of all the energy it generates, exporting 32.8%. In comparison, in the OPCL and uncontrolled load scenarios, no energy is used to heat water and 2.03kWh in the case of the latter. In both cases, the % of energy produced by Solar PV that is self-consumed on site is lower

(20% and 31.5%) than the PowerStore case. Both these scenarios in comparison with the PowerStore scenario, are not maximising their self-consumption. They are exporting at higher rates and using less of the energy that they produce to heat their water systems.

The analysis on June and December, demonstrates that customers with PowerStore are more effectively harnessing the Solar PV energy that they produce. They are reducing their reliance on the grid, whilst also reducing exports (reverse-flows) on the network.

4.4.3 Analysing Site B

Sample	Season	Energy used by site	Energy produced by Solar PV	Solar self-consumption	Solar exported	% of all solar PV produced exported	Solar used by HW	% of HW from Solar PV
PowerStore HEMS	Winter	32.94kWh	22.45kWh	17.91kWh	4.54kWh	20.2%	12.09kWh	66.5%
OPCL	Winter	32.94kWh	22.45kWh	5.83kWh	16.62kWh	74%	0	0
Uncontrolled Load	Winter	32.94kWh	22.45kWh	7.13kWh	15.32kWh	68.2%	1.30kWh	7.2%
PowerStore HEMS	Summer	26.26kWh	50.32 kWh	19.31kWh	31.01kWh	61.6%	6.08kWh	99.6%
OPCL	Summer	26.26kWh	50.32 kWh	13.23kWh	37.09kWh	73.5%	0	0
Uncontrolled Load	Summer	26.26kWh	50.32 kWh	16.15kWh	34.17kWh	67.9%	2.91kWh	47.7%

Table 17: Describes the energy use on a site (B) with a large PV system but medium hot water usage on a typical day in June and December.

Table 17 describes the consumption profile of site B. Site B typically needs 32.94kWh of energy per day in June. It produces 22.45 kWh of Solar PV. In the PowerStore scenario, 12.09 kWh of Solar PV is used to heat water or 66.5% of the energy required. Self-consumption sits at 79.8% of all energy generated with 20.2% exported.

In the OPCL and uncontrolled load scenarios, 0 and 1.3kWh of energy generated is used by the hot water system respectively. In the case of OPCL, customers use 26% of energy generated and export 74%, whilst in scenario uncontrolled load, customers use 37.8% of energy generated and export 68.2%.

In both scenarios, the % of energy produced by Solar PV that is being self-consumed on site is lower (26% and 37.8%) than the PowerStore scenario at 79.8%.

A PowerStore customer in comparison to these scenarios, would be maximising Solar PV self-consumption and reducing both exports and imports to the network.

In summary this high-level analysis shows that a smart hot water system better improves the outcomes from Solar PV, by enhancing the ability of customers to exploit

Solar PV generated. As a consequence, exports to the grid and imports from the grid are reduced, positively impacting reverse-flow issues and the resilience of the network. Outcomes are more pronounced in the summer, but the pattern repeats for winter also.

4.5 Complementing technologies – batteries, solar HWS

While water heating is a major source of energy use in the home, other appliances can significantly contribute to home energy usage, whilst some are even complementary to the proposed hot water systems such as batteries and solar HW systems. The project also sought to explore the potential for pool pump and air conditioning control adapters to provide aggregated demand response.

Given the focus of this project has been driving sales of water heaters, limited market research has been performed to date on these other technologies.

4.6 Retrofit vs PowerStore for wider roll out of program

There are currently several makes of “solar diverter” style retrofits on the market. They are devices intended to be fitted in-line with the power supply to a conventional electric water heater, and their function is to throttle the power supply to the water heater to match available surplus solar PV power generation, thereby minimising power drawn from the grid. Further, some solar diverters can also change the power supply source to the water heater, in response to a change in tariff or other signalling.

Key functionality differences between the PowerStore solution and retrofits revolve around the ability to optimise against a ToU electricity plan, optimise solar self-consumption and to manage amenity for the homeowner. The PowerStore and HEMS solution prioritises customer amenity to ensure that customers do not run out of hot water. Available hot water is measured constantly and compared against usage profiles from learning heuristics to determine how much hot water needs to be available by time of day and day of week. Then the system prioritises use of available, excess solar power before reverting to grid power that is scheduled against the ToU retail energy plan.

An early assessment of smart hot water systems against ‘retrofits’, compared functions such as smart technology, legionella control, tank temperature profile, etc. against solar-smart electric water heaters. The main results summarising the advantages and disadvantages of retrofits are summarised below:

	Advantages	**Disadvantages**
Retrofit of conventional electric water heater compared to solar-smart electric water heaters using solar diverters	Lower cost than replacement Provides some intelligence and control	No legionella control No tank temperature profile Shorter warranties Less adaptable to harsh Australian conditions

	Advantages	Disadvantages
	Takes advantage of existing infrastructure More installation work required on site to retrofit the water heater Beneficial for customers with a recently acquired water heater (less than 4-5 years old)	No real time monitoring of available hot water May damage water heater thermostat if switching frequently

Table 18: Comparing retrofit.

Implications for the wider rollout of the Solahart Retrofit product

The Solahart Retrofit product:

- Is designed for ease of installation and full compliance with safety and standards requirements.
- Includes multiple tank water temperature sensors to ensure amenity as this is a key feature of any water heater control.
- Includes intelligent heating control to provide grid benefits and customer value through tariff arbitrage.
- Is designed for an expected market with functioning water heaters that are under 4-5 years old.

Figure 22: Solahart Retrofit Kit Photo.

5 Conclusion and recommendations

This report is the final knowledge share report and provides an overview of activities and learnings at close. It explores the importance of the project, insofar as demonstrating how actively controlled hot water systems could be harnessed to provide aggregated demand response, and deliver a host of benefits to customers, the network and the market.

Progress of the Project

The technology developed for the project consisted of a technology platform stack based on the following components.

- Customer DER - PowerStore and PowerStore Lite smart hot water system
- Hardware for detection and logging of frequency disturbance events ("FCAS events"), namely the MASS-compliant CET-HD-PM2-1 Power Meter suitable for FCAS
- Hardware and software systems for coordinating local response of site DER to FCAS events (CET-HD-EMU Energy Management Unit)
- Cloud systems and processes for automatic collection, time-alignment, post-processing and reporting of FCAS event data
- End user monitoring and configuration portal *atHome*
- Fleet management system for HEMS sites (*onWatch* Portal)
- Fleet management system for FCAS group management, configuration, monitoring and FCAS event reporting.
- InGrid Solution to facilitate operational management of the solution.

This report provides an overview of progress achieved against the following:

- Technical development
- Commercial/financial business case
- Regulatory and market findings
- Customer recruitment

It describes novel aspects of the project including the innovation around Gateway Lite, PowerStore Lite and inGrid VPP platform. Sales and marketing were challenging and the project was forced to evolve its approach during delivery. Modelling was also done on the limited installations, highlighting the potential commercial benefits to customers, opportunities for networks to manage load and insights on implications on the market.

Also included in this report are latest learnings relating to the following topics as directed by the funding authorities on the following topics:

- Network Load coordination options for HW load
- Management options for the solar generation 'duck curve'
- NEM arbitrage strategies
- Options to maximise behind the meter solar consumption
- Competing complementing technologies such as batteries and solar HW systems
- Retrofit vs PowerStore for wider roll-out of program

The report also provides some early analysis on how a smart hot water system can:

- Mitigate issues around reverse-flow, the duck curve and the management of minimum demand on the network
- Improve commercial outcomes by reducing reliance on grid energy to heat water systems and improve general self-consumption

Key Findings

1. Household energy load to heat water represents a significant proportion of overall household energy usage. Energy for water heating ranges from as low as 20% of all energy consumed in summer, to a high of over 35% in spring. While energy demand for hot water peaks in winter, the percentage as a proportion of all energy usage in the home peaks in spring as overall energy demand (much due to space heating in winter) reduces more quickly in spring than hot water usage. The high impact of hot water on energy usage in spring aligns with the worst period of minimum demand problem in South Australia. See Section 6.7 Appendix C1.
2. Actively controlled hot water systems (smart heaters with Home Energy Management Solutions) source a much **higher proportion of energy to heat water from the household solar PV** system than alternatives of OPCL or uncontrolled hot water systems (see Section 6.8 Appendix C2). This **improves solar self-consumption** (Section 6.9 Appendix C3) and **reduces export** (Section 6.14 Appendix C8), as compared to homes with water heating on OPCL or through uncontrolled hot water systems.
3. Actively controlled hot water systems (smart heaters with Home Energy Management Solutions) can contribute significantly to reducing **peak export** on the network – see Section 6.10 Appendix C6 when compared to OPCL or uncontrolled hot water systems. This is a benefit to the distribution network that could be shared further with consumers.
4. Actively controlled hot water systems (smart heaters with Home Energy Management Solutions) can contribute significantly to reducing **peak demand** on the network – (see Section 6.11 Appendix C5) when compared to OPCL or uncontrolled hot water systems. This is a benefit to the distribution network that could be shared further with consumers.
5. There are significant potential **savings for electricity retailers** in their wholesale energy and network costs for customers with actively controlled hot water systems (smart heaters with Home Energy Management Solutions) when compared to customers with water heaters on OPCL or uncontrolled water heaters. Savings range across the year between 30% in winter and 85% in summer against OPCL, or between 70% and 95% for uncontrolled water heaters. See Section 6.12 Appendix C6.
6. **Costs to the consumer** from heating water on OPCL or with actively controlled hot water systems (smart heaters with Home Energy Management Solutions) are significantly lower than using an uncontrolled water heater. OPCL and actively controlled hot water attract similar costs between spring and autumn, with an advantage to OPCL in winter. See Section 6.13 Appendix C7. Given the significant benefits to the distribution network (reduced peak demand and reduced peak export) and to the electricity retailer (reduced wholesale energy and network

costs) from the use of smart heaters and HEMS over OPCL, a redistribution of costs should be considered to incentivise customers to invest in the advanced smart heater and HEMS technologies.

The work done to date highlighted the need for further analysis on how smart hot water systems can perform in a fleet, how they can be configured to deliver FCAS value and broader network value. Further work needs to be done also on how economic benefits are distributed amongst participants, the customer, the retailers, the aggregators and the Network.

6 Appendices

6.1 Appendix A – Competitive Analysis

	Solahart PowerStore	Electric Storage Hot Water	iStore (Solargain) Hot Water Storage	Paladin-2	Green Catch Power	Blue Catch Power
	Smart Hot Water Heater (Energy Storage)	Traditional Electric Hot Water System	Smart Heat Pump + Hot Water (Energy Storage)	Power Diverter	Power Diverter	Power Diverter
Water storage capacity	**315L**	315L	270L	NA	NA	NA
Maximum Heating Element Capacity	**Variable 0 to 3.6kw**	3.6kw	3.4kw	6kw	4.8kw	4.8KW
STANDARD FUNCTIONALITY						
Ability to store excess solar PV power	**Yes**	No	Yes	No	No	No
Connection to off-peak (Controlled load)	**No**	Yes	Yes	Yes	Yes	Yes
Connection to Solar PV power	**Yes**	Yes	Yes	Yes	Yes	Yes
Works with Time of Use tariffs	**Yes**	Yes	Yes	No	Yes	Yes
Smart technology (Built into the HWS)	**Yes**	No	Yes	No	No	No
Legionella control	**Yes**	Yes	Not specified	No	No	No
Minimum amenity mode	**Yes**	No	No	NA	NA	NA
Tank Temperature profile	**Yes**	No	No	NA	NA	NA
Dual element to optimise solar contribution	**Yes**	No	Yes	NA	NA	NA
CONNECTIVITY						
Ability to connect to a Home Energy Management System	**Yes**	Yes	Yes	Yes	No	Yes
Hot water availability monitored in real time with feedback	**Yes**	No	Yes	No	No	No
OPERATIONAL						
Specifically designed for Australia's tough conditions	**Yes**	Yes	Yes	No	No	No
Payback	Varies by situation / geography	NA	Not Specified	Approximately 2-3 Years	Approximately 2-3 Years	Approximately 2-3 Years
Warranty	**10 Years 3 Years for components**	12 Years	5 Years 2 Years for Refrigeration & Electrical 1 Year components	2 Years	5 Years	5 Years
Price (RRP inc GST)	**$4,675**	$1,556 Installed	TBC	$790 Uninstalled	$1,000 Installed	$1,700 Installed

(Continued over)

	The Power Diverter (Covertel)	Intelligent Immersion I2W Solar Diverter	AWS SunMate 2.0	SolarEdge Immersion Heater Controller	Load Shift Timer	Battery (Typical)
	Power Diverter	Power Diverter	Power Diverter	Power Diverter	Timer with battery back-up	Battery Storage
Water storage capacity	NA	NA	NA	NA	NA	NA
Maximum Heating Element Capacity	4.8KW	3kw	100W to 3.6kw	Up to 3.6kw	NA	NA
STANDARD FUNCTIONALITY						
Ability to store excess solar PV power	No	No	No	No	No	Yes
Connection to off-peak (Controlled load)	Yes	Yes	Yes	Yes	No	Yes
Connection to Solar PV power	Yes	Yes	Yes	Yes	Yes	Yes
Works with Time of Use tariffs	Yes	Yes	Yes	Yes	No	Yes
Smart technology (Built into the HWS)	No	No	No	No	No	NA
Legionella control	No	No	No	No	NA	NA
Minimum amenity mode	NA	NA	NA	NA	NA	NA
Tank Temperature profile	NA	NA	NA	NA	NA	NA
Dual element to optimise solar contribution	NA	NA	NA	NA	NA	NA
CONNECTIVITY						
Ability to connect to a Home Energy Management System	Yes	Integrated HEMS	Yes	Yes	No	Yes
Hot water availability monitored in real time with feedback	No	Yes	No	No	NA	Yes, via HEMS
OPERATIONAL						
Specifically designed for Australia's tough conditions	No	No	No	Yes	No	No
Payback	Approximately 2-3 Years	Approximately 2-3 Years	Approximately 2-3 Years	Approximately 2-3 Years	12 months	12-15 Years
Warranty	5 Years	3 Years	5 Years	5 Years	12 months	10 Years
Price (RRP inc GST)	$900 Uninstalled	$650 Uninstalled	$850 Uninstalled	TBC	$220 DIY	Approx $12,000

Table 19: Early market research on the hot water system market.

6.2 Appendix B1 – Energy charts – category SHW-LPV

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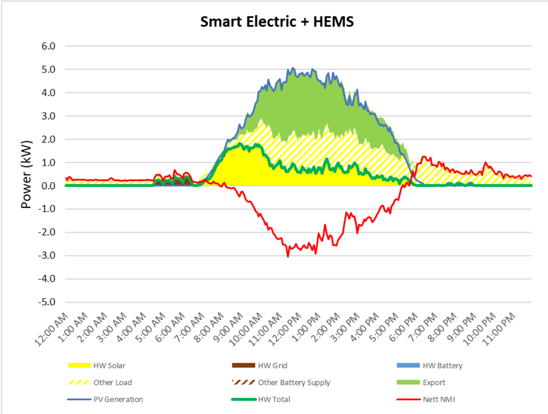
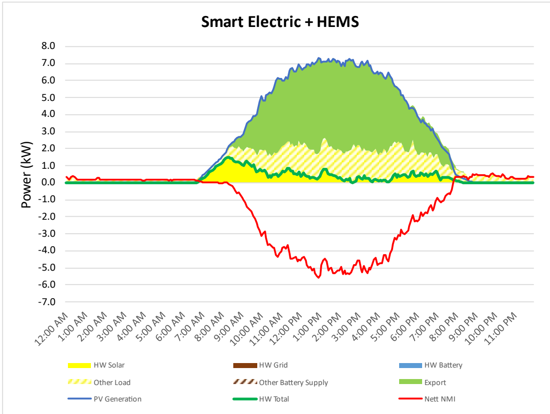
<tr><td>
</td><td>
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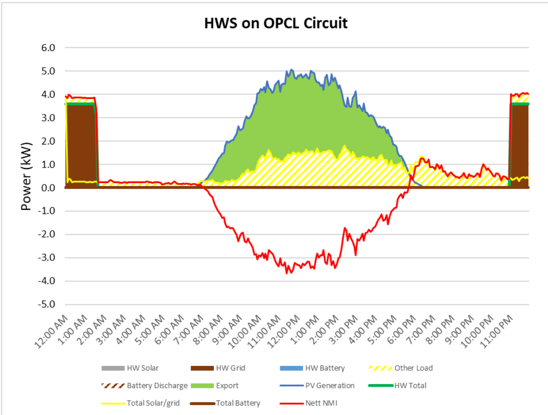
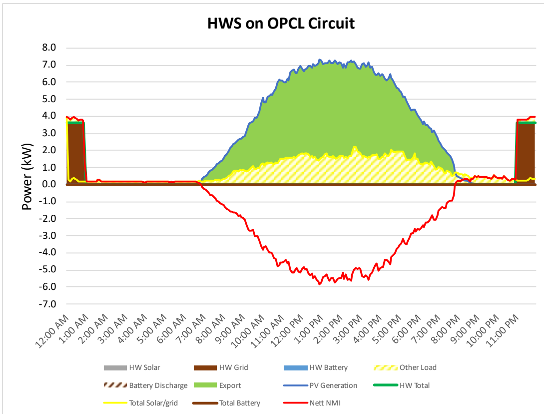
<tr><td>
</td><td>
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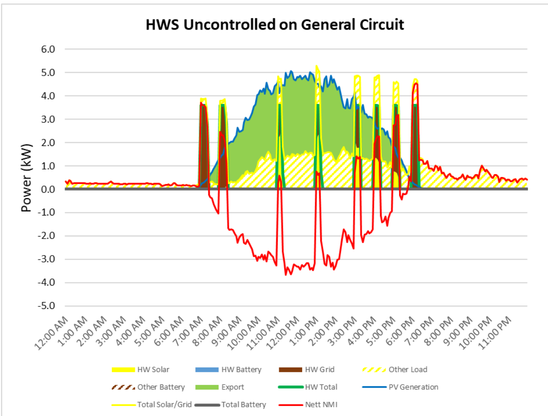
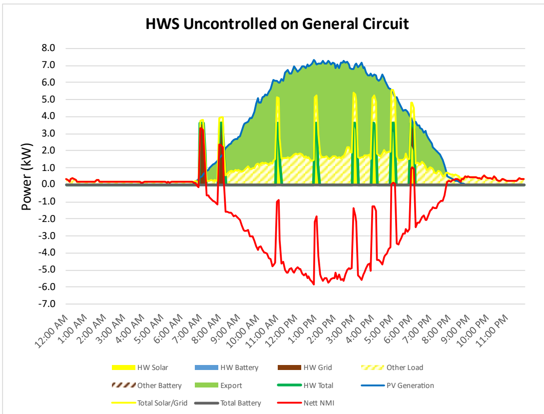
<tr><td>
</td><td>
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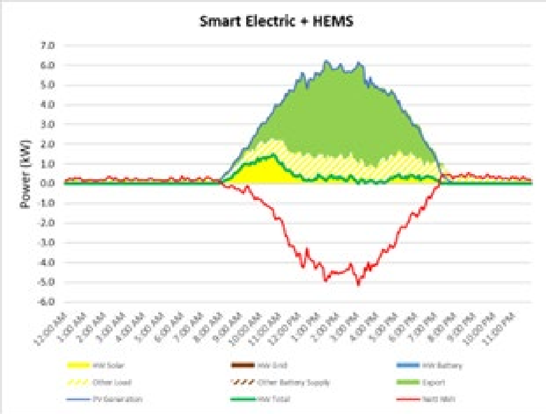	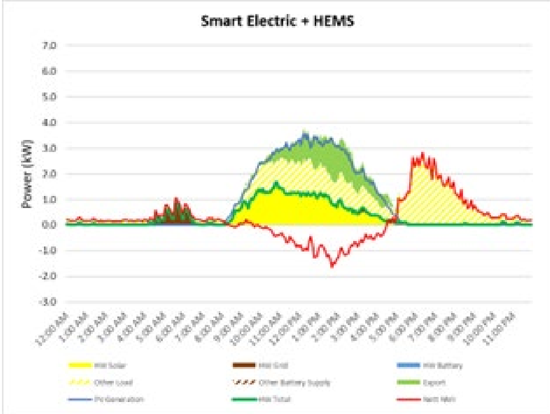
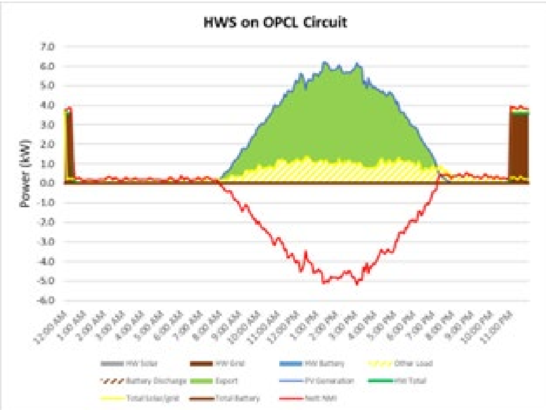	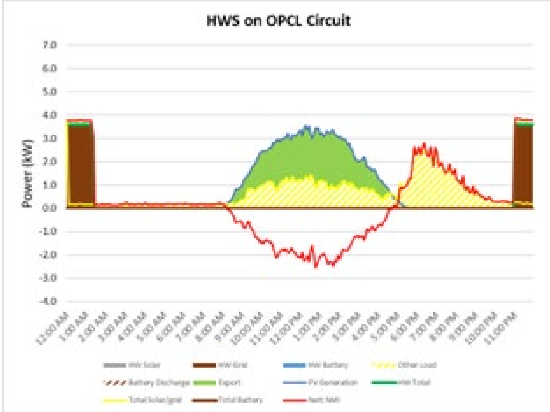
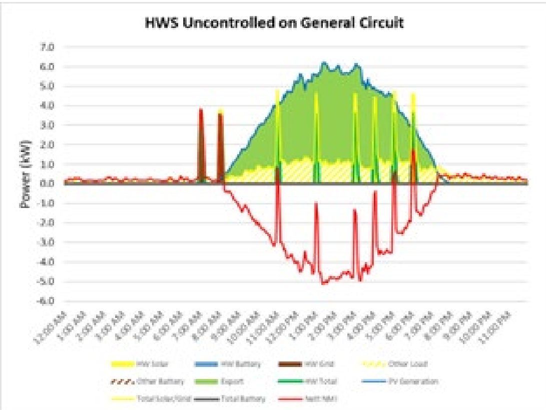	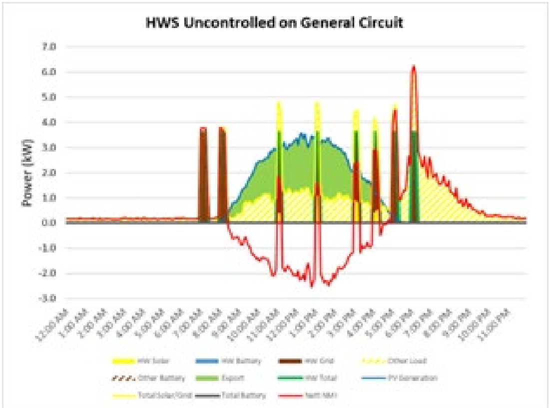

6.3 Appendix B2 – Site analysis – category SHW-MPV

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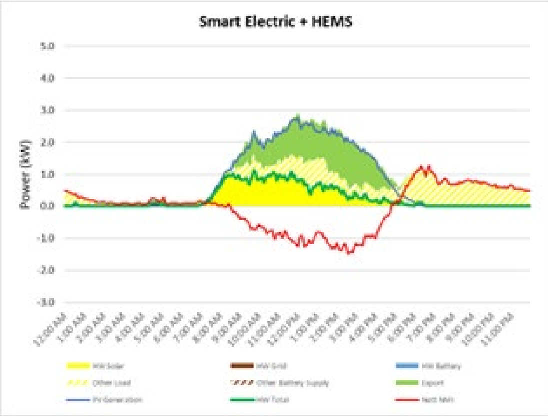
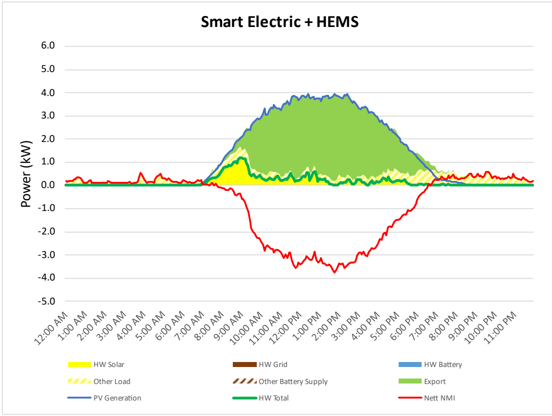
<tr><td>
</td><td>
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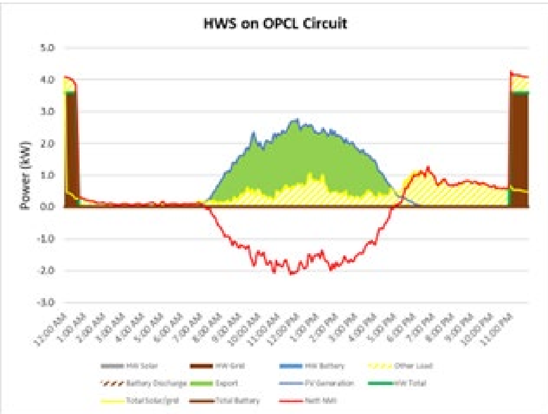
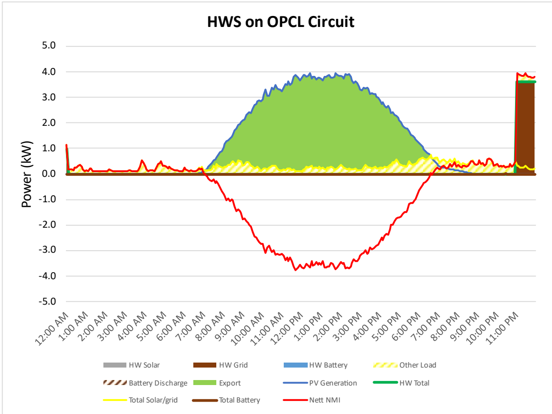
<tr><td>
</td><td>
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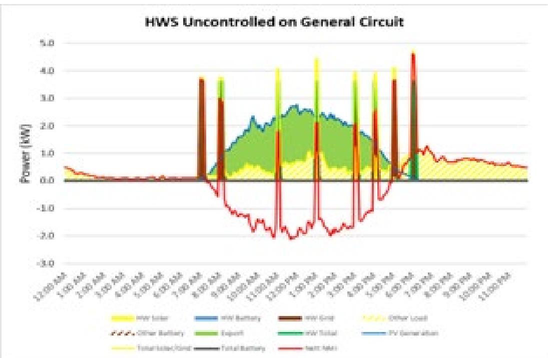
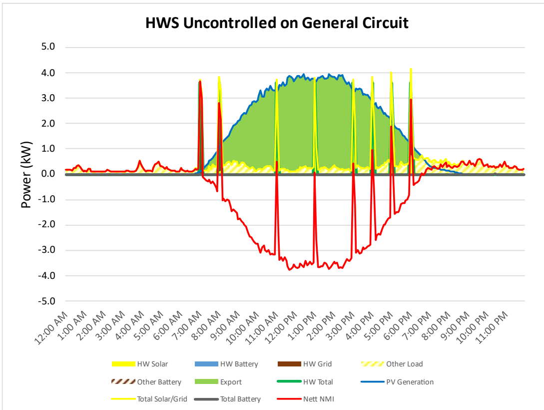
<tr><td>
</td><td>
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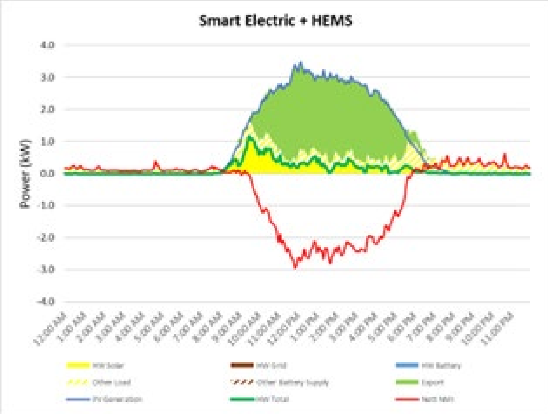
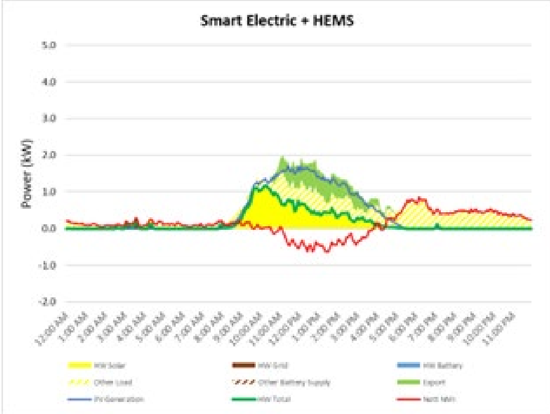
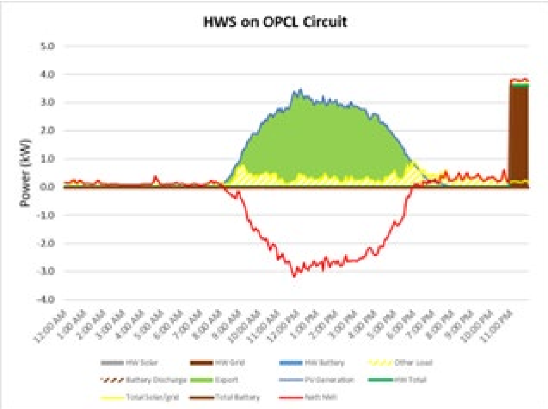
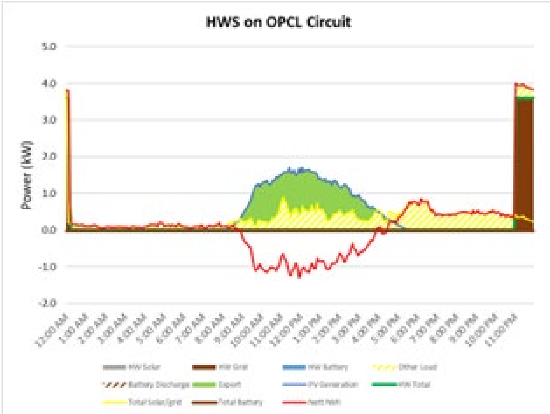
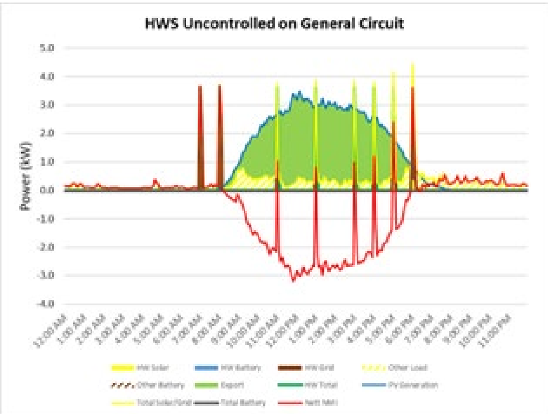
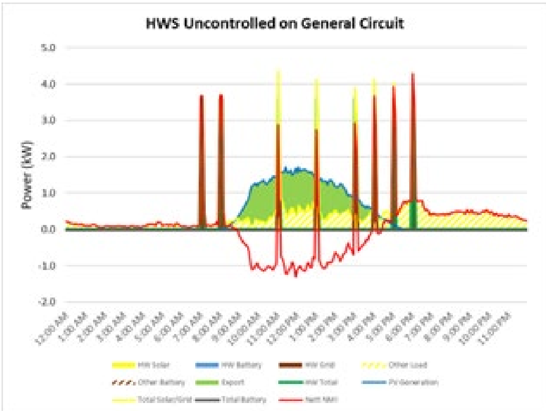
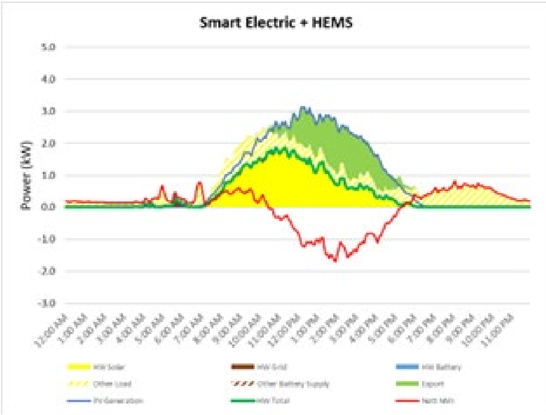
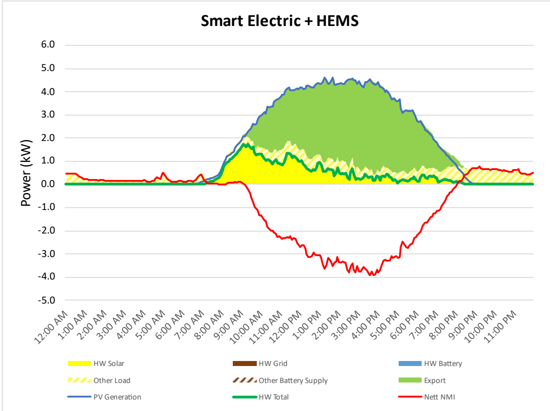
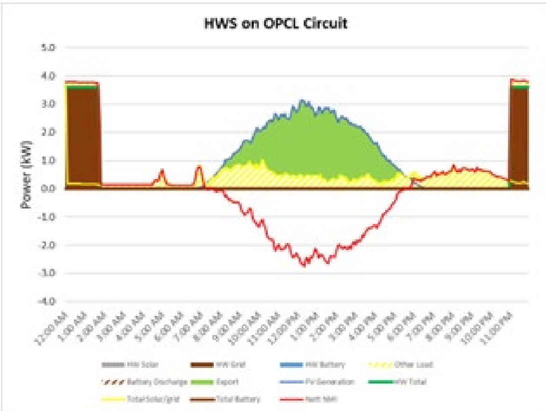
	
	
	

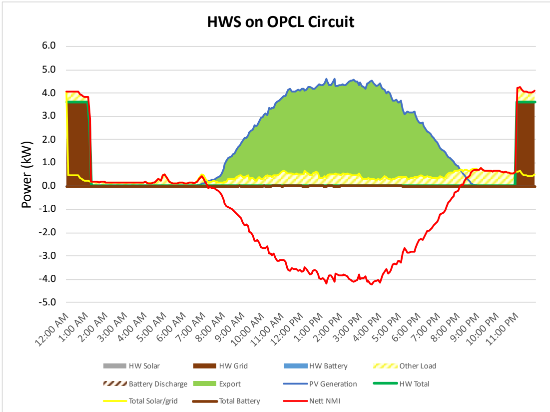
6.4 Appendix B3 – Site analysis – category MHW-MPV

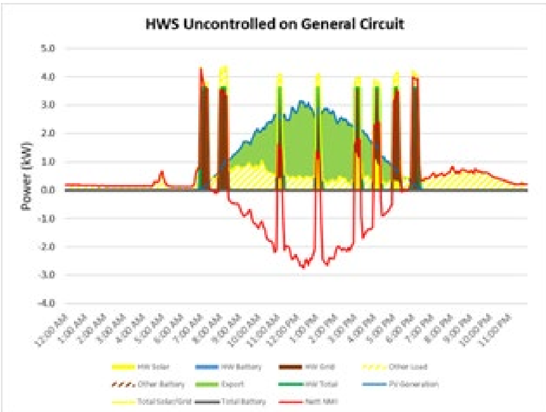
September (Spring)	December (Summer)

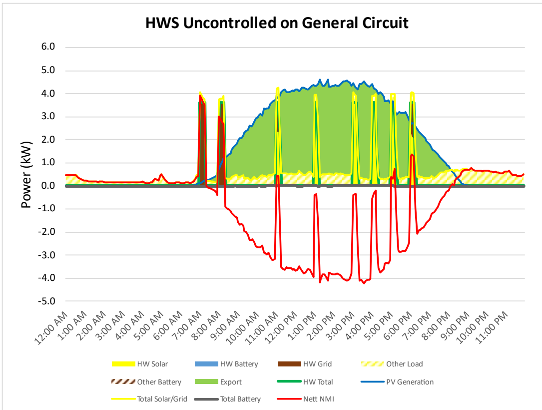


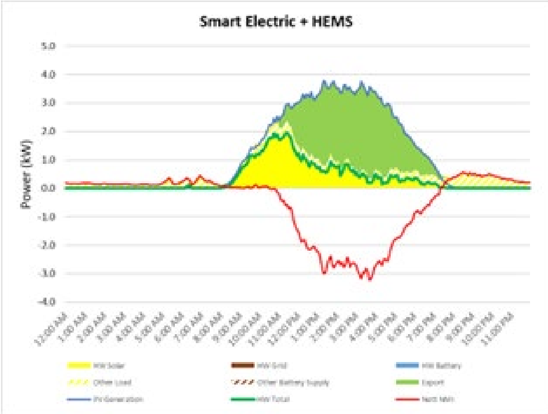
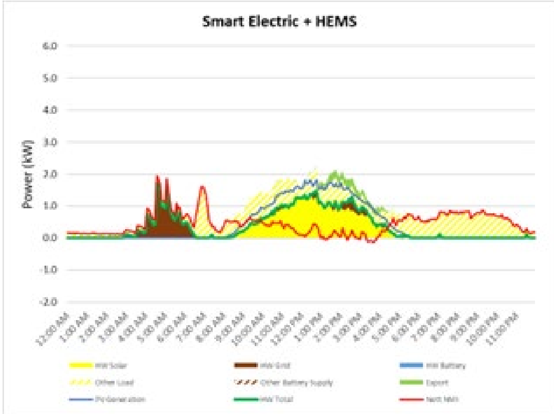
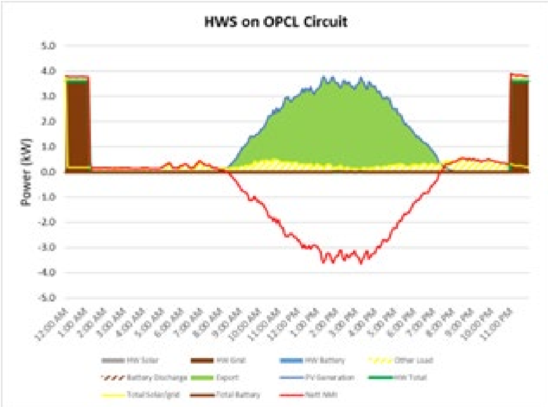
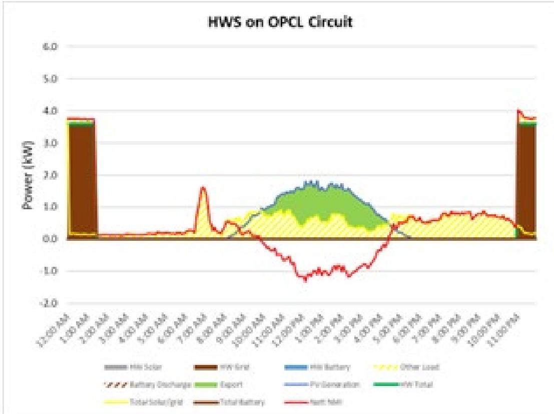
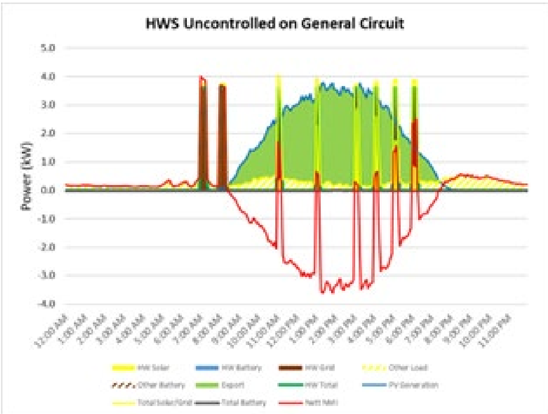
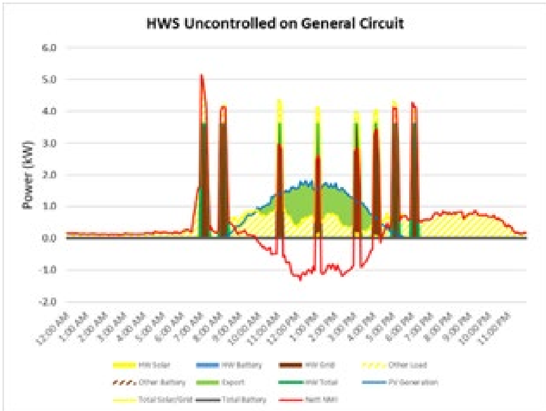






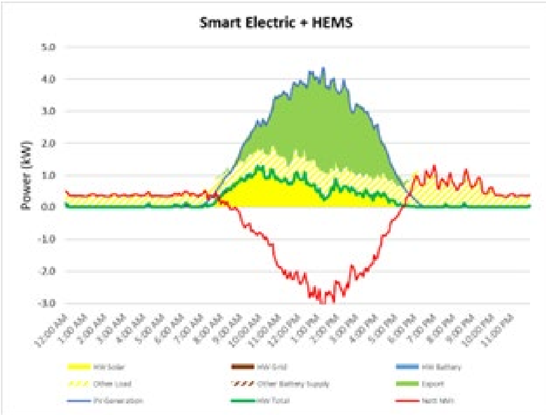




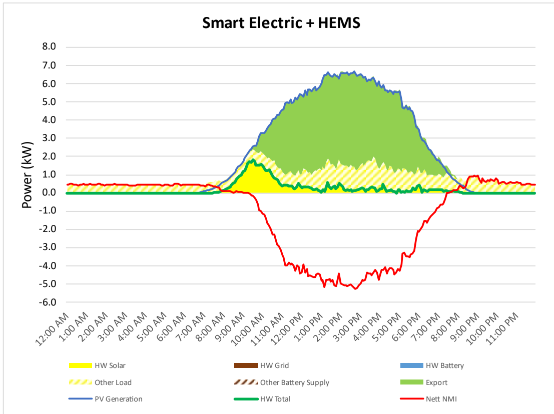
March (Autumn)	June (Winter)
	
	
	

6.5 Appendix B4 – Site analysis – category MHW-LPV

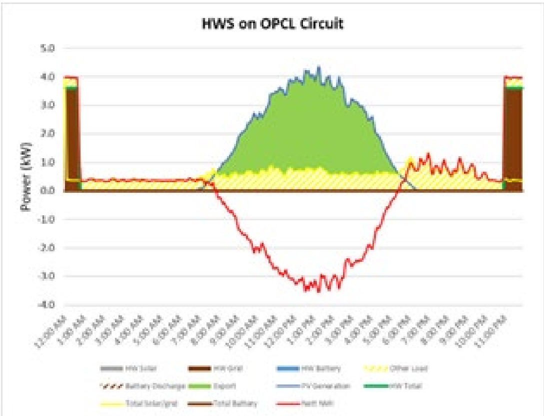
September (Spring)



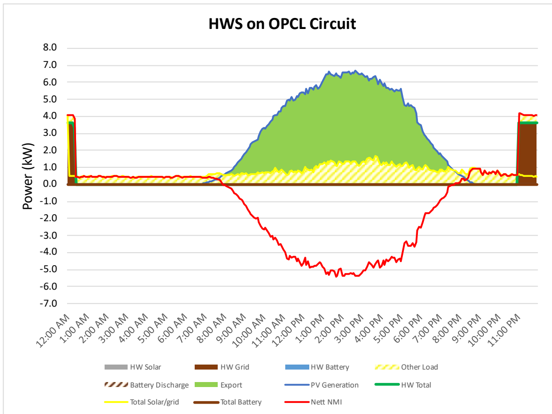
December (Summer)



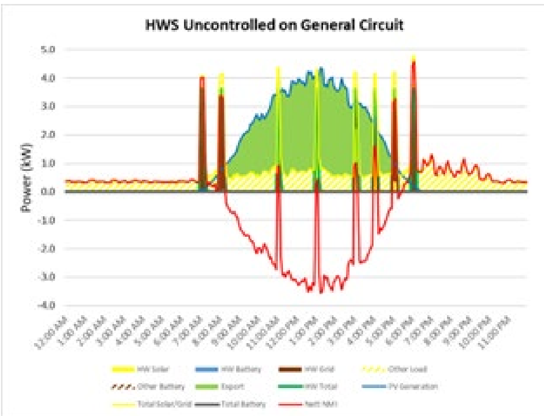
September (Spring)



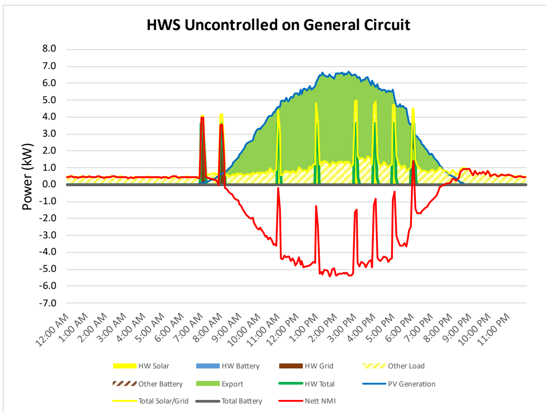
December (Summer)

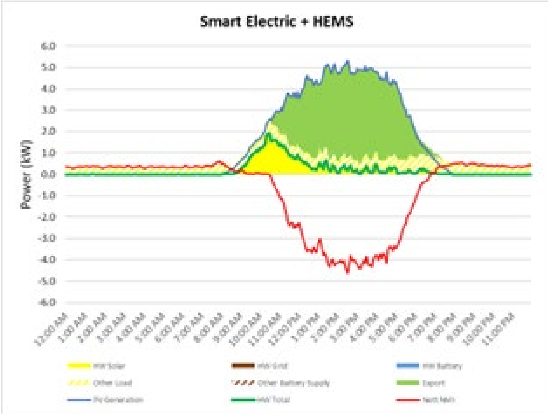
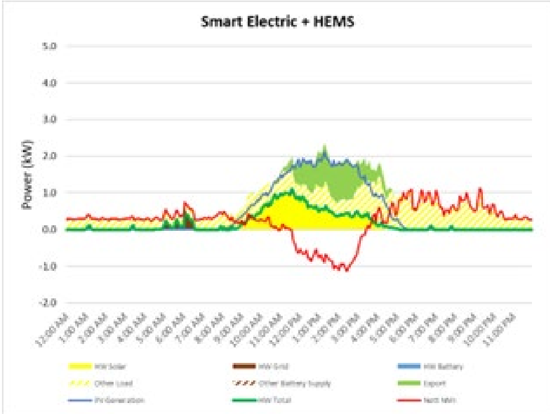
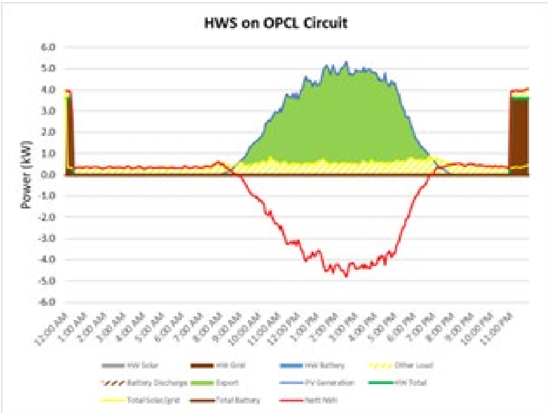
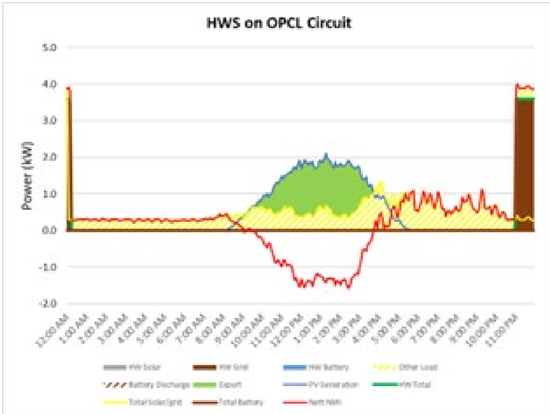
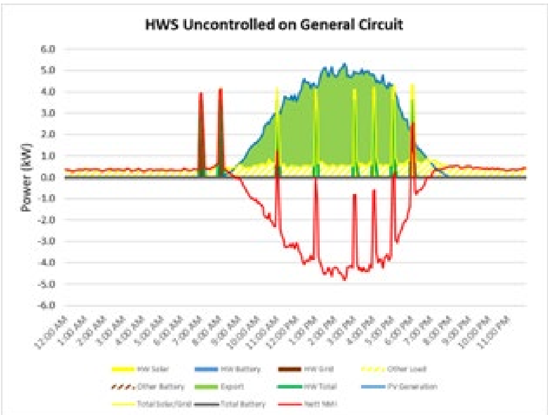
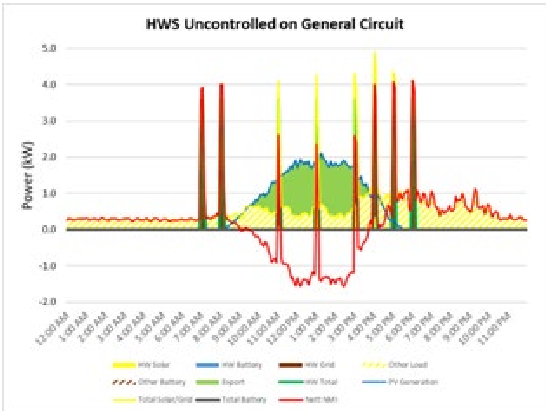


September (Spring)



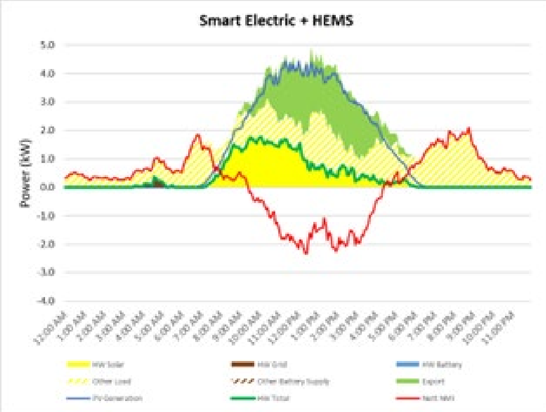
December (Summer)

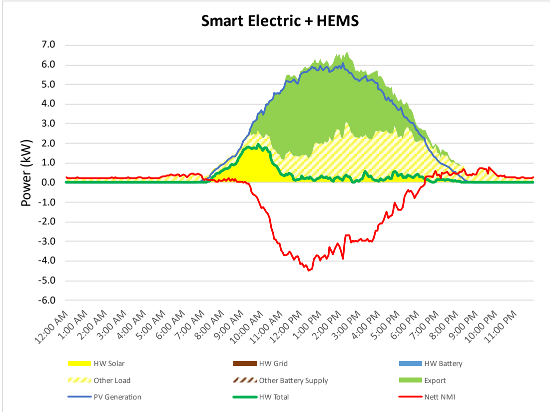


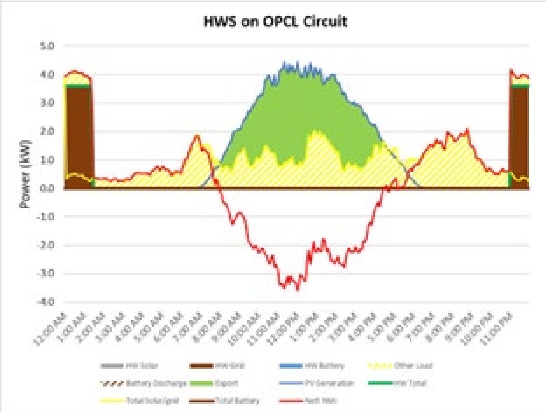
March (Autumn)	June (Winter)
	
	
	

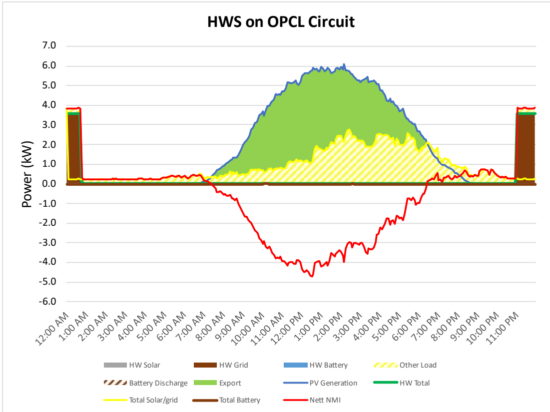
6.6 Appendix B5 – Site analysis – category LHW-LPV

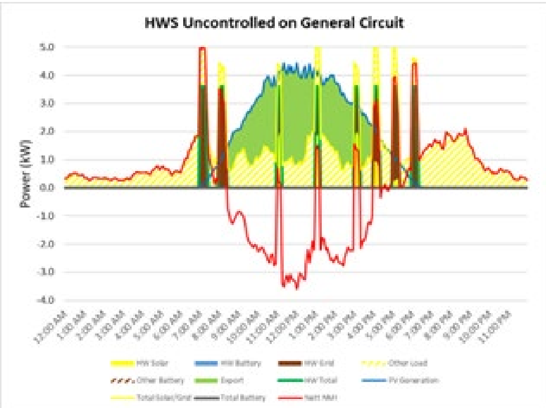
September (Spring)	December (Summer)

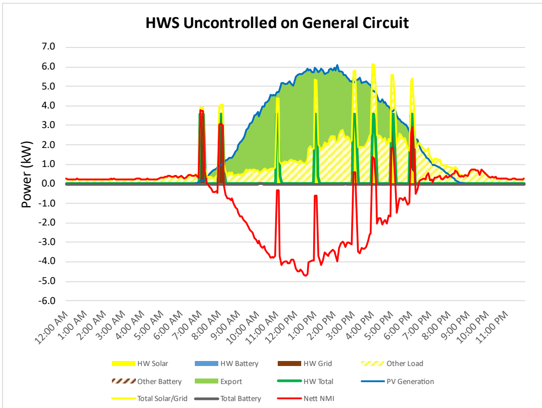


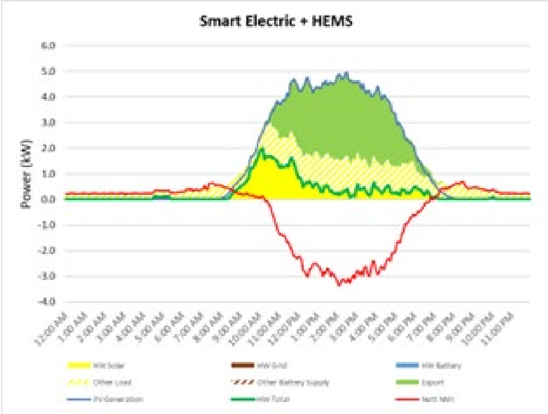
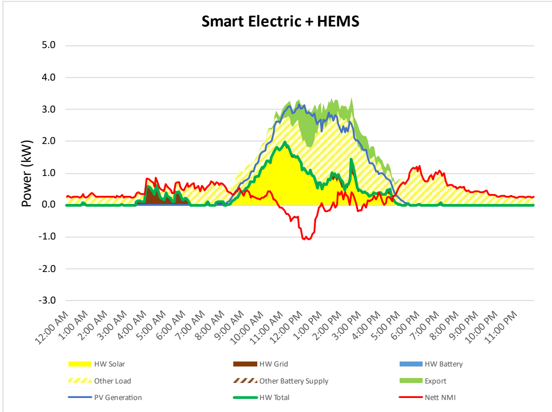
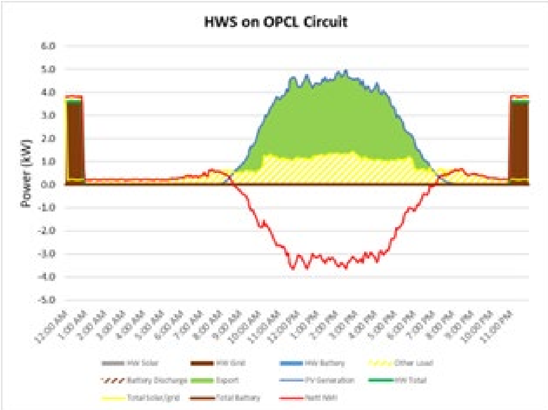
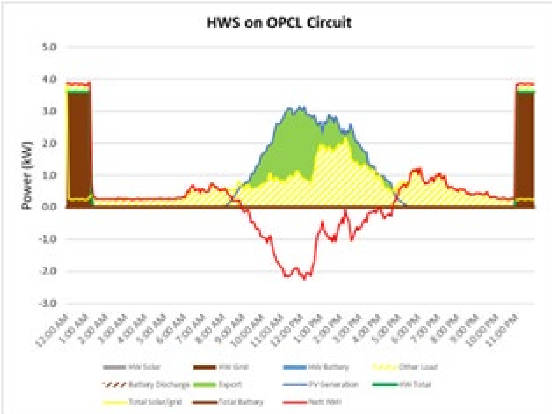
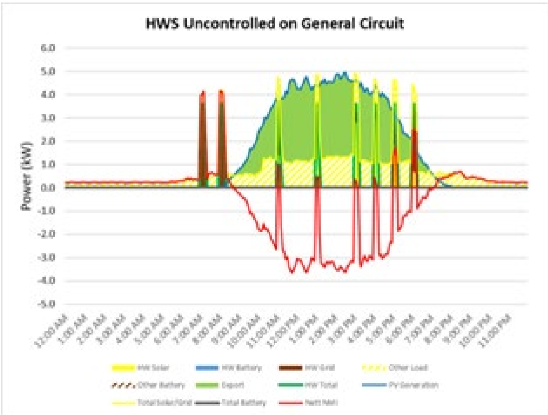
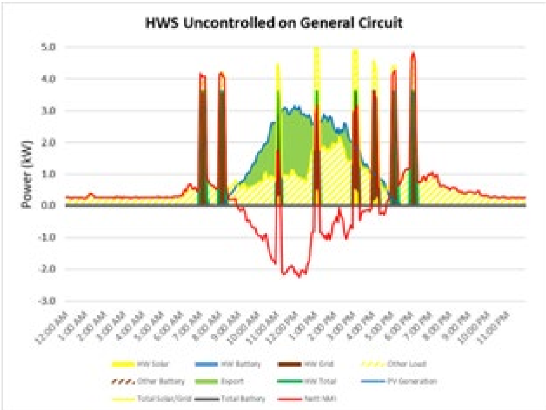




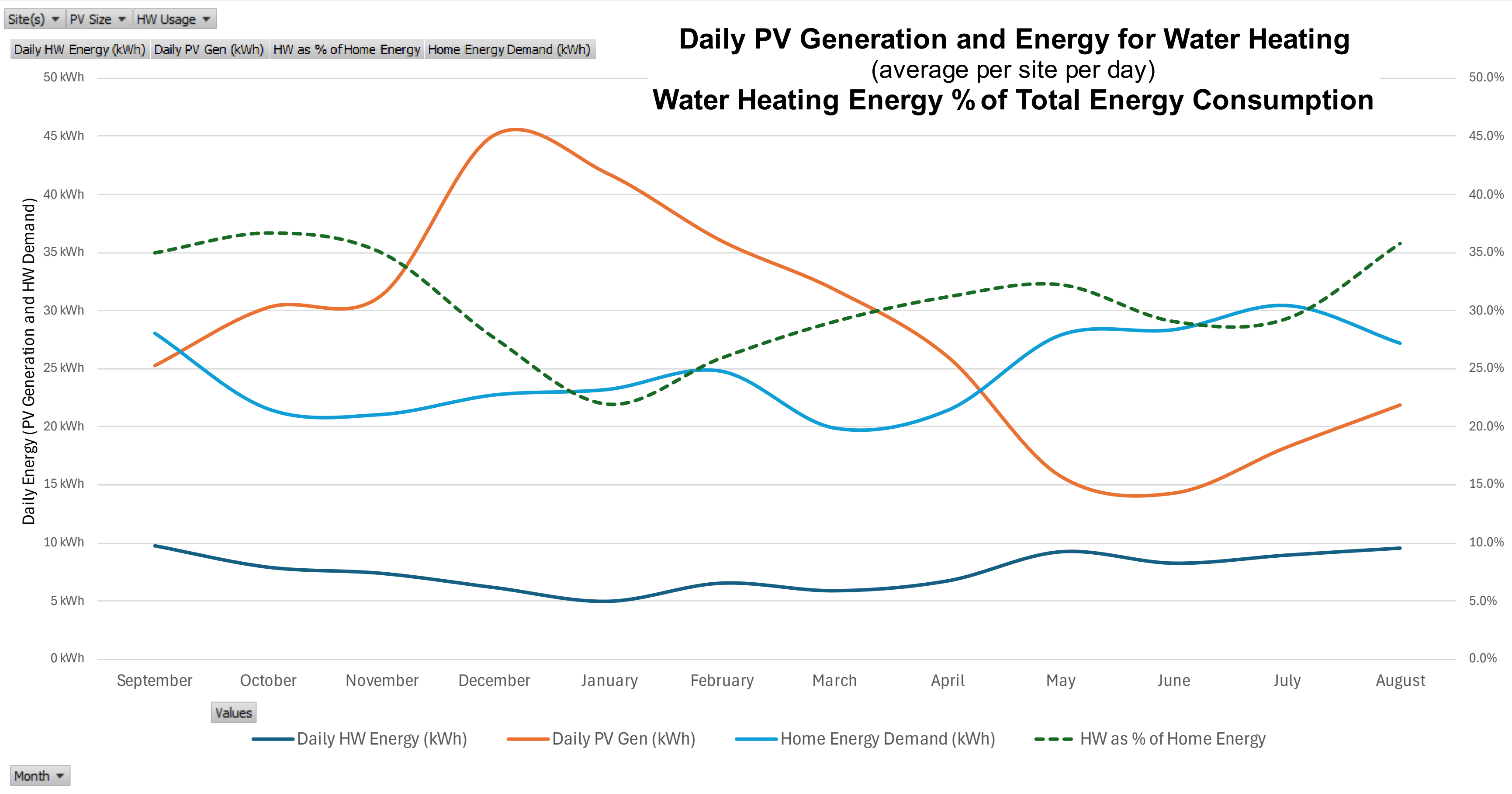




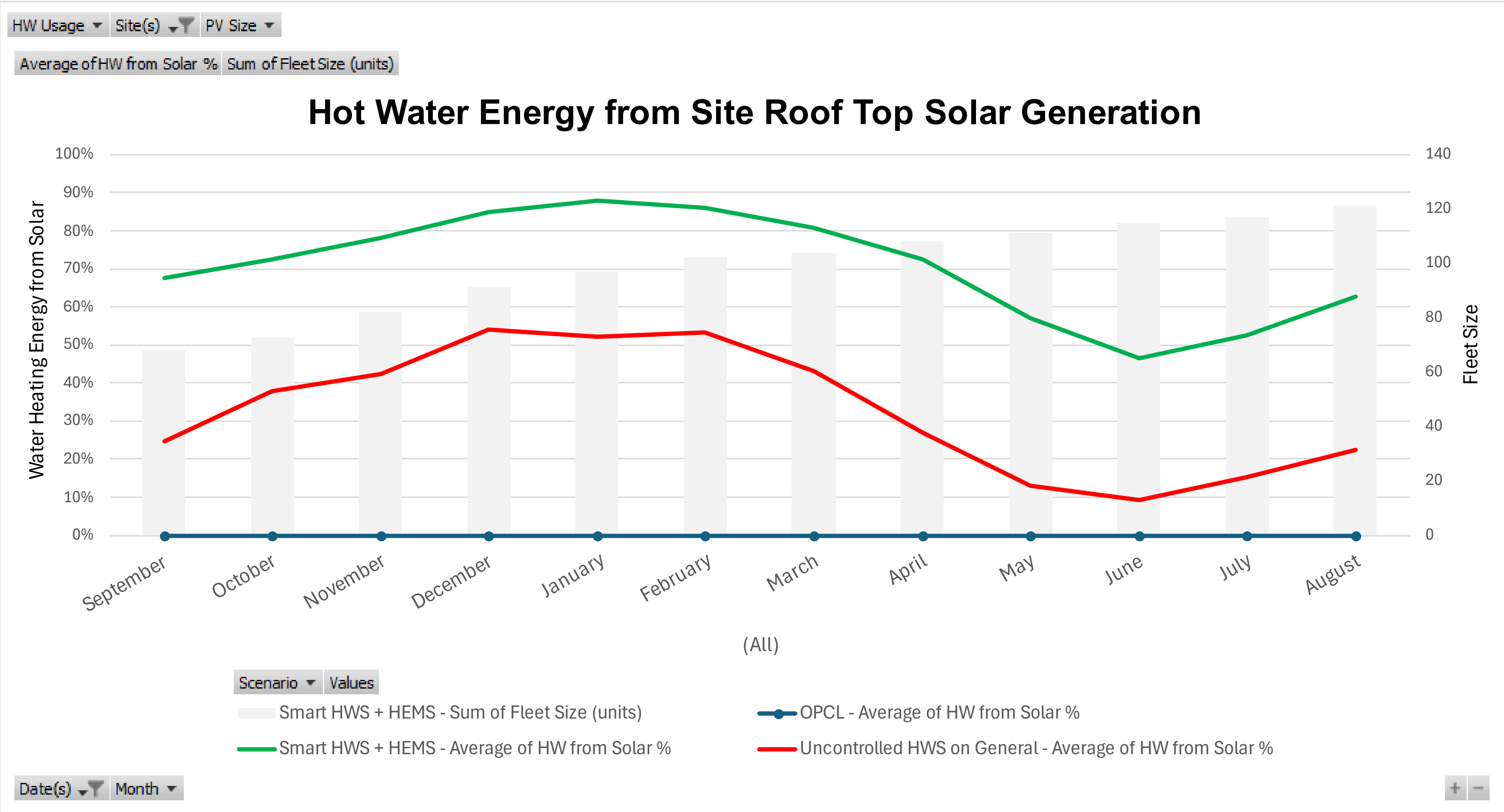


March (Autumn)	June (Winter)
	
	
	

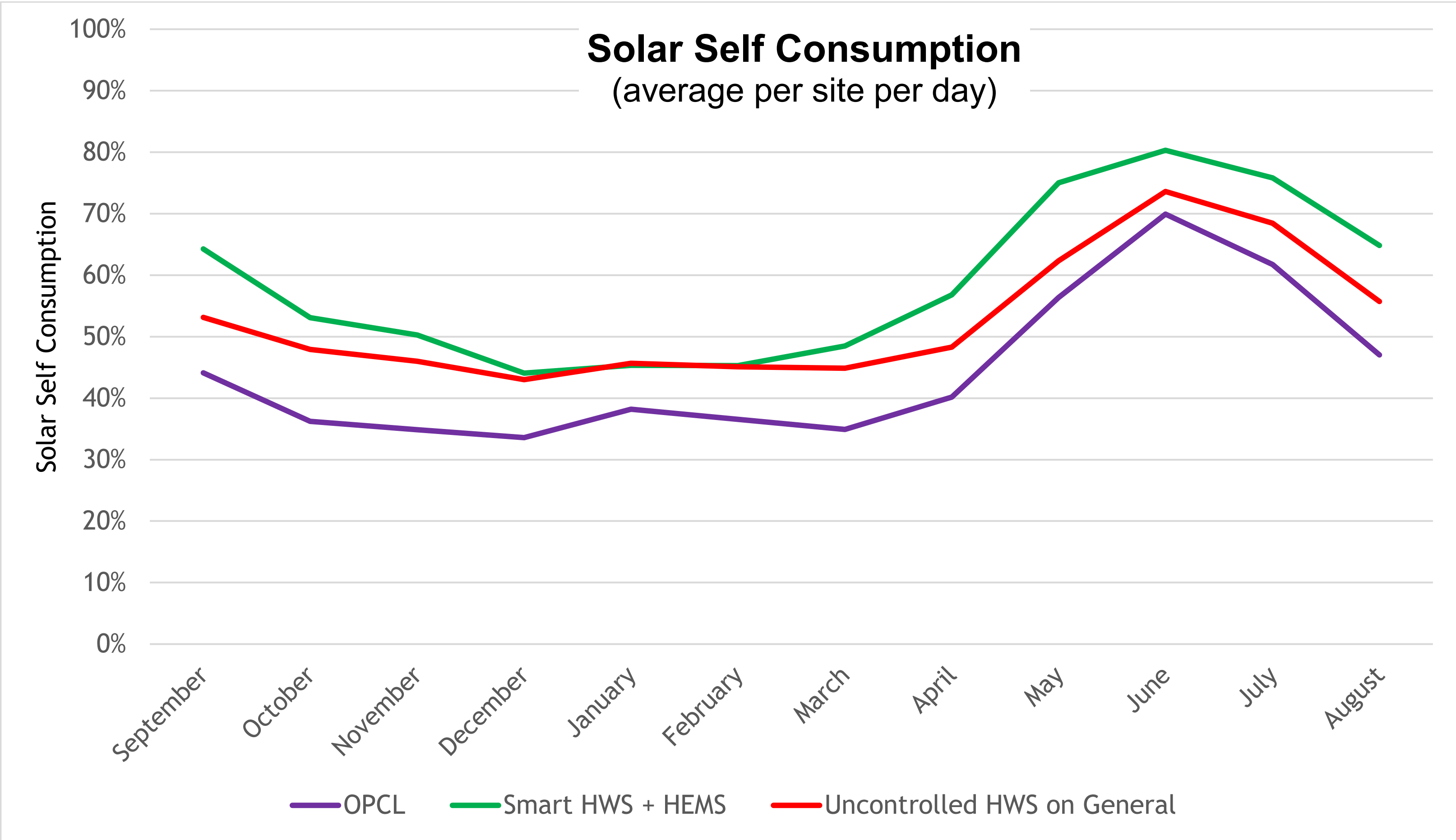
6.7 Appendix C1 – Solar PV Generation and Hot Water Energy Demand



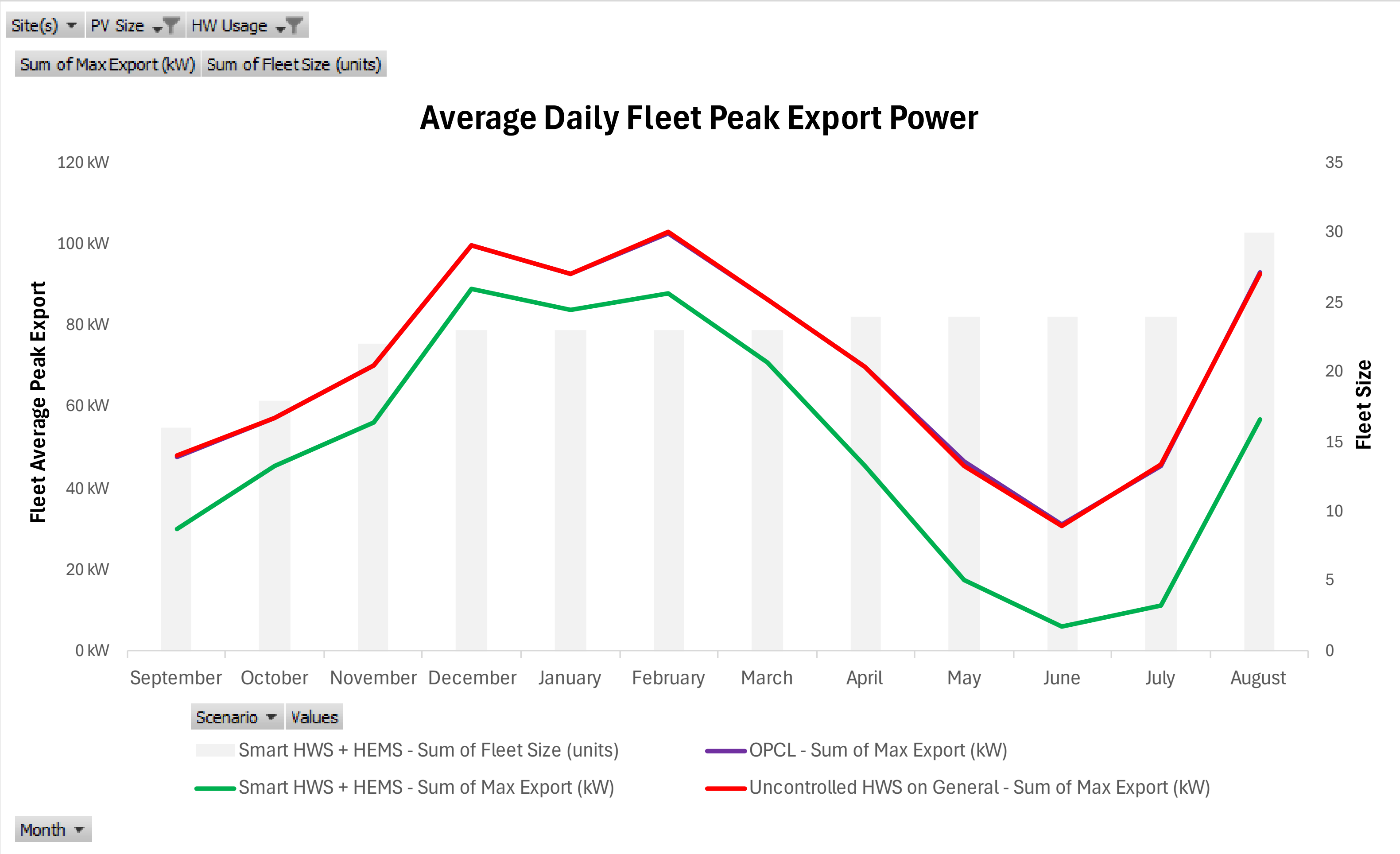
6.8 Appendix C2 – Hot Water Energy from Site Roof Top Solar



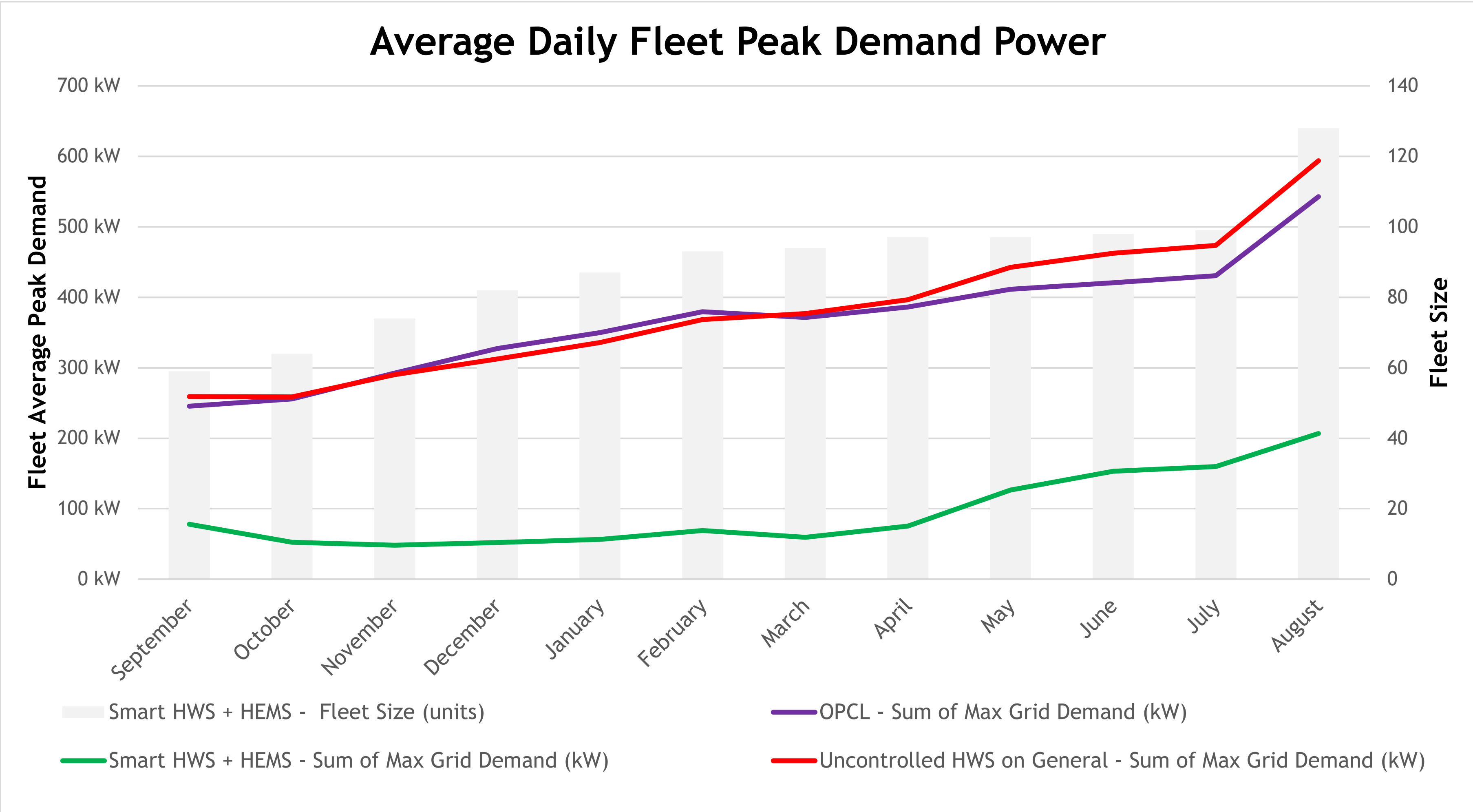
6.9 Appendix C3 – Average Roof Top Solar Self-Consumption



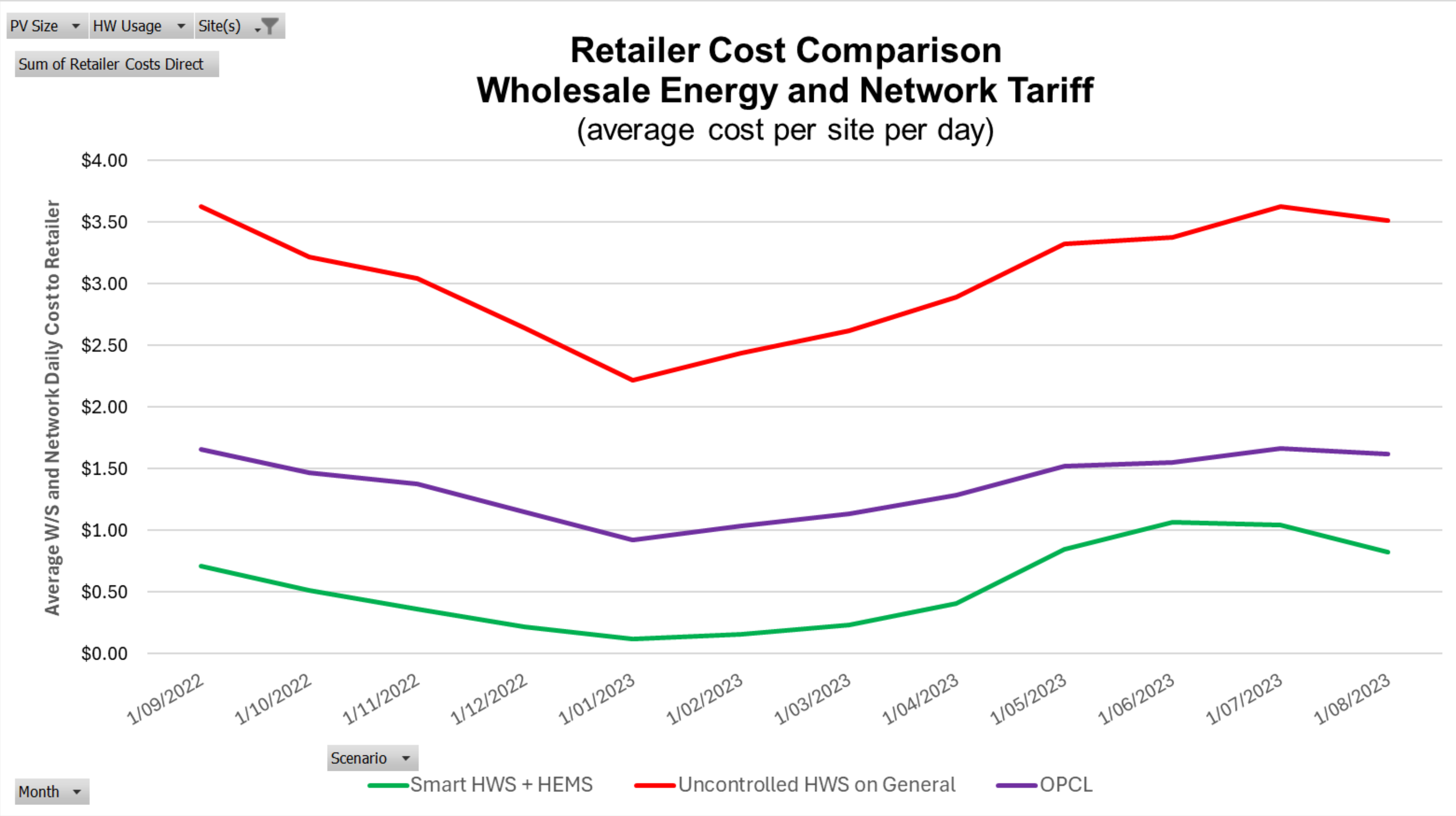
6.10 Appendix C4 – Fleet Peak Export



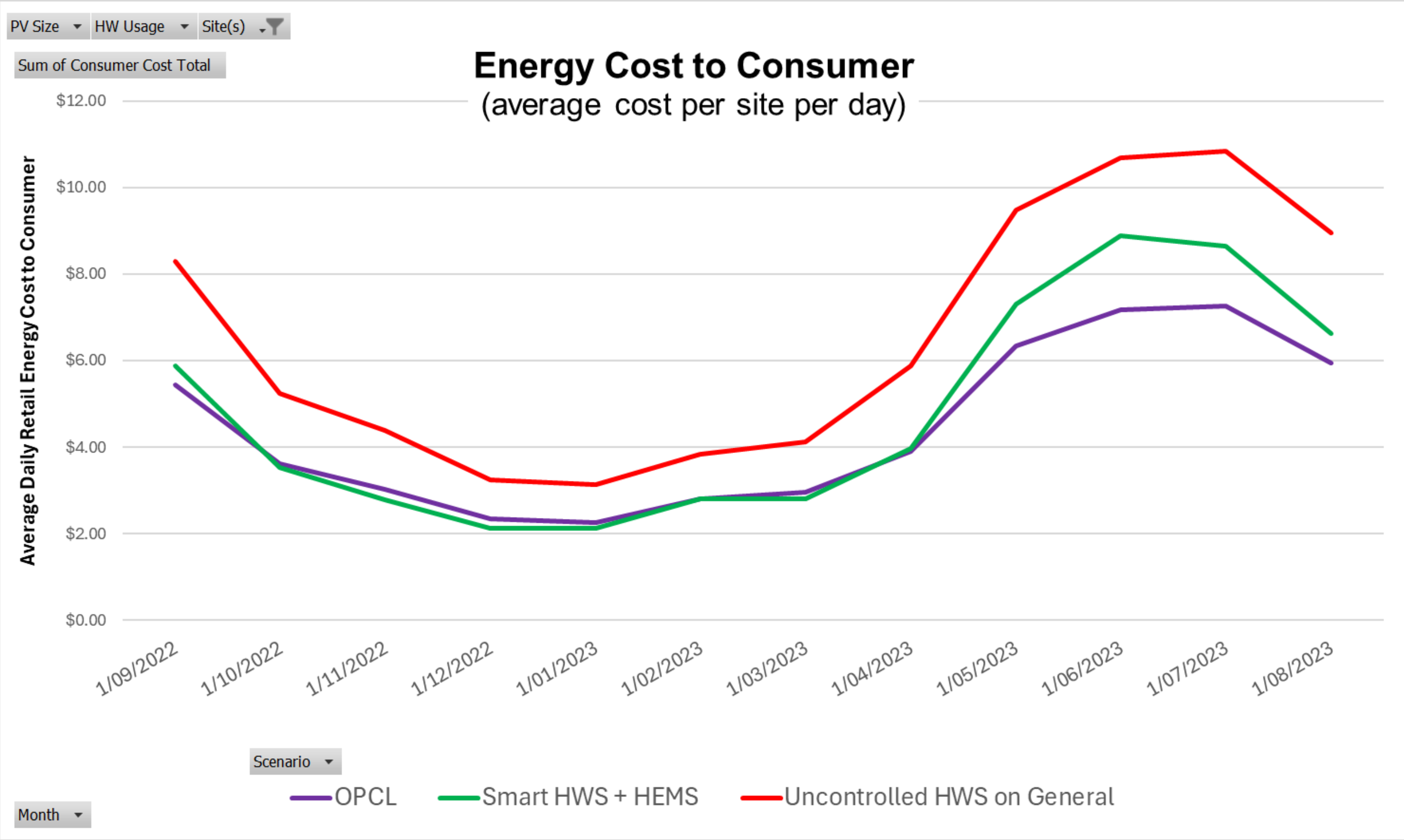
6.11 Appendix C5 – Fleet Peak Demand



6.12 Appendix C6 – Wholesale Energy and Network Costs to Retailer



6.13 Appendix C7 – Retail Energy Costs to Consumer



6.14 Appendix C8 – Daily Fleet Exported Energy