Turning household water heating systems into MW batteries to support integration of renewables and consumer energy resources (CER)

Deep dive into opportunities and challenges

School of Photovoltaic and Renewable Energy Engineering (SPREE) Research Seminar
Wed, 4th June, 2025

Dr. Baran Yildiz,
Collaboration on Energy and Environmental Markets,
School of Photovoltaic and Renewable Energy Engineering (SPREE), UNSW

Acknowledgment of country

"I would like to acknowledge the Bidjigal and Gadigal people that are the Traditional Custodians of this land. I would also like to pay my respects to the Elders both past and present and extend that respect to other Aboriginal and Torres Strait Islanders who are present here today."

Findings from two projects:

Project SolarShift

PLUS ES South Australia Flexible Demand Trial

Project team:
- Ruby Klisser,
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- Dr. Baran Yildiz

Our research is supported by Australian Centre for Advanced Photovoltaics (ACAP)

Today's content

1) Project motivation

2) Real-world trials:

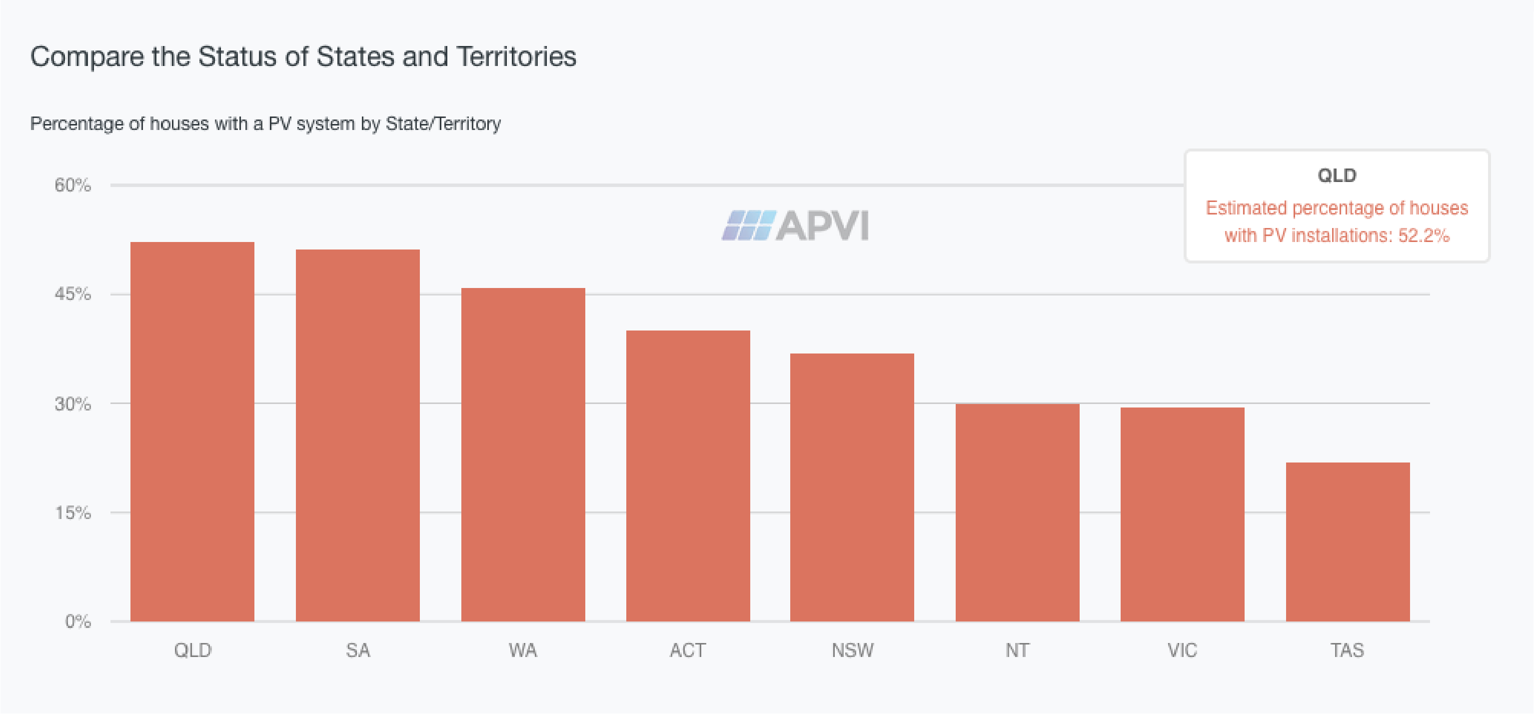
- South Australia PLUS ES Flexible Demand Trial
- Endeavour Energy Off-peak + Trial

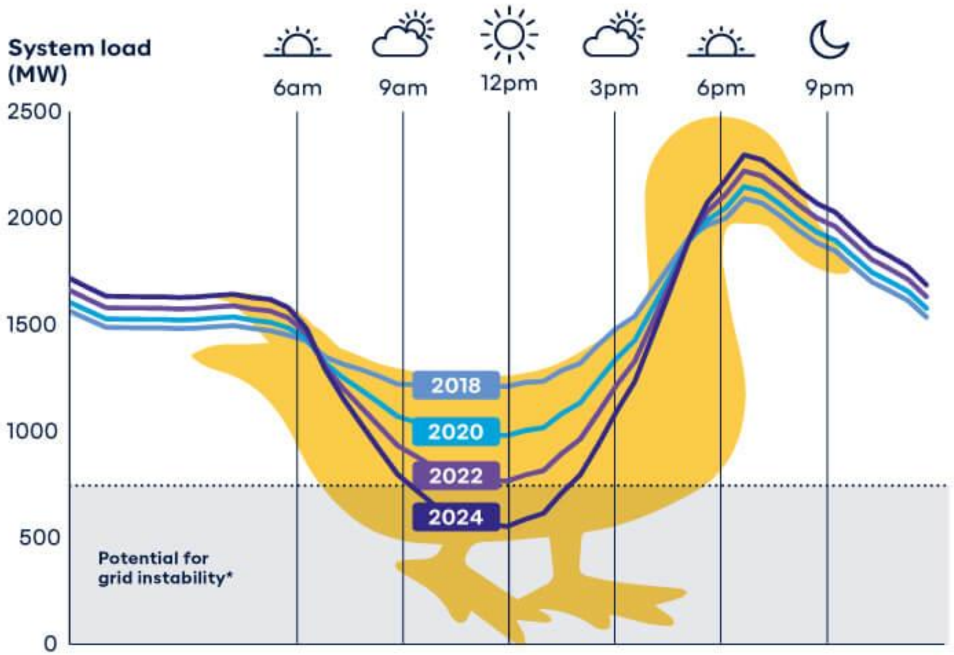
3) SolarShift Project Thermal Modelling Results

4) SolarShift Project Customer Hot Water Roadmap

5) Contributions &future research directions

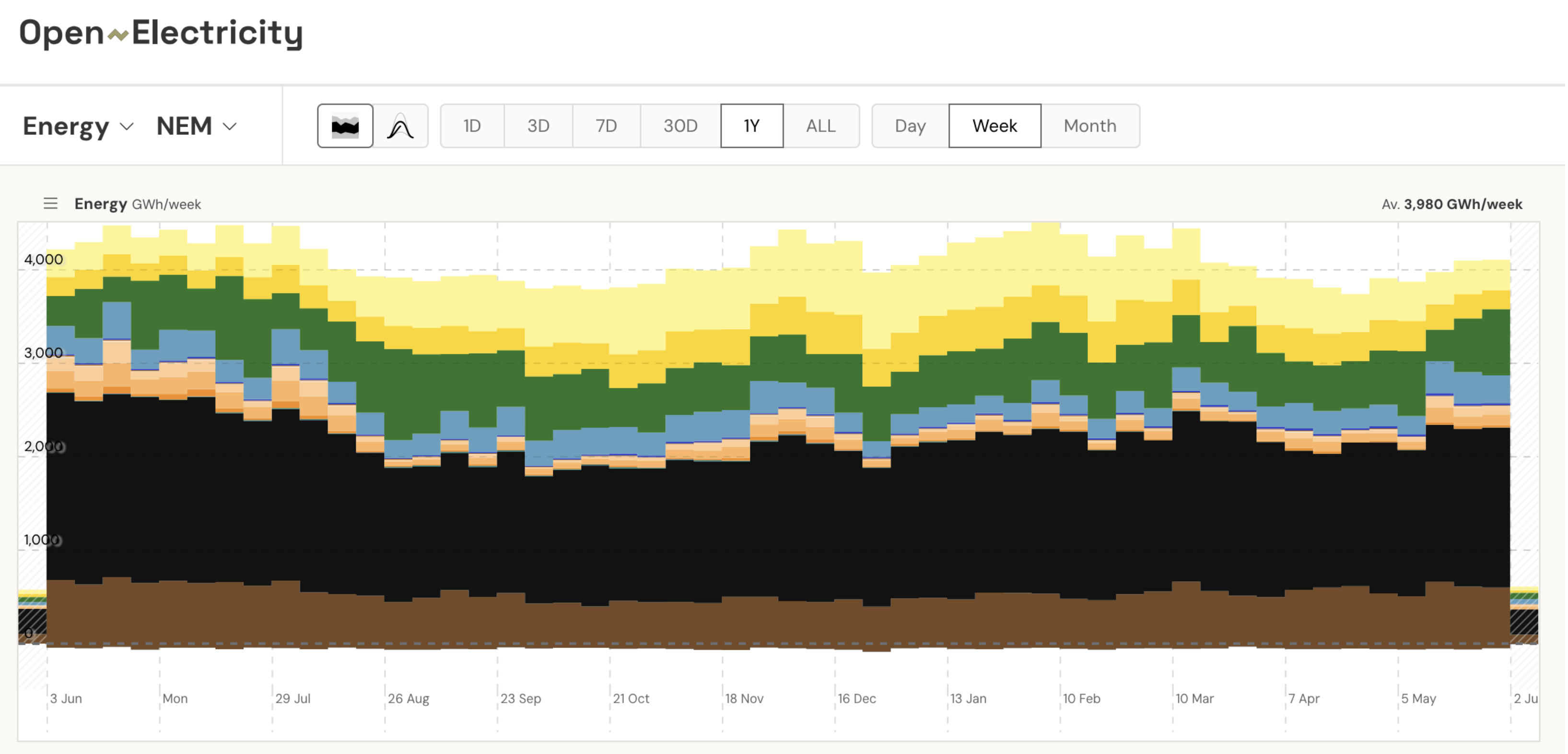
Project motivation: Increasing rooftop solar





References: APVI 2025, Synergy,

Project Motivation: increasing rooftop solar



27 May 2024 – 8 Jun 2025

Detailed	Energy GWh	Contribution to demand	Av.Value $/MWh
Sources			
Solar (Rooftop)	27,764	12.7%	$33.46
Solar (Utility)	16,791	7.7%	$47.20
Wind	30,263	13.9%	$72.78
Hydro	13,362	6.1%	$174.86
Battery (Discharging)	861	0.4%	$247.96
Gas (Waste Coal Mine)	399	0.2%	$109.74
Gas (Reciprocating)	366	0.2%	$221.60
Gas (OCGT)	3,290	1.5%	$331.98
Gas (CCGT)	5,763	2.6%	$193.87
Gas (Steam)	1,228	0.6%	$186.51
Distillate	54	0.02%	$962.16
Bioenergy (Biomass)	353	0.2%	$129.85
Coal (Black)	86,673	39.7%	$128.61
Coal (Brown)	30,936	14.2%	$94.44
Loads	**-3,185**		
Pumps	-2,070	-0.9%	$15.16
Battery (Charging)	-1,115	-0.5%	$32.96
Net	**214,918**		
Renewables	**88,532**	40.6%	

Project motivation: Integration challenges

NEWS

Rooftop solar PV provides 107.5% of grid demand in South Australia

By George Heynes

November 18, 2024

Power Plants, Grids

Asia & Oceania, Southeast Asia & Oceania

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South Australia is aiming to run on 100% wind and solar PV by 2027. Image: CSIRO.

Rooftop solar PV in South Australia broke the 100% grid demand contribution on Sunday afternoon, peaking at 107.5%.

According to OpenNEM, at around 13:45 on 17 November, rooftop solar PV in South Australia provided 107.5% of the state's demand, standing at around 1,720MW. This is the latest milestone the state has achieved, having broken the 100% threshold last month.

Powerlines may be limiting savings Australians can make from solar, UNSW research suggests

By consumer affairs reporter Liz Hobday and the Specialist Reporting Team's Penny Timms

7.30 Solar Energy

Mon 17 Aug 2020

Rolf Wittwer put solar panels on his house, expecting to save money on energy. Instead, they kept shutting down. *(ABC News: Tony Hill)*

abc.net.au/news/solar-powerlines-alr... Share article

Do we really need a rooftop solar button – and are households treated fairly with PV, batteries and EVs?

AAP Image/Dan Himbrechts

Sophie Vorrath Nov 19, 2024

What is renewable energy curtailment and how does it affect rooftop solar?

By technology reporter James Purtill

ABC Science Solar Energy

Wed 16 Feb 2022

Your rooftop solar panels may be quietly switching off in the middle of the day. *(Reuters: Tim Wimborne, file photo)*

abc.net.au/news/solar-how-is-it-affect... Share article

Australia's energy operator wants emergency powers to switch off rooftop solar. What does it mean for households?

By energy reporter Daniel Mercer

Solar Energy

Sat 7 Dec

Rooftop solar can at times meet more than half of the total demand across the national electricity market. *(ABC News: Glyn Jones)*

abc.net.au/news/rooftop-solar-emerg... Share article

RENEW ECONOMY

Tuesday, June 3, 2025

Home » Solar » Some households lose 20 per cent of their solar output from grid curtailment

Some households lose 20 per cent of their solar output from grid curtailment

Sophie Vorrath Mar 30, 2022

SOLAR UTILITIES

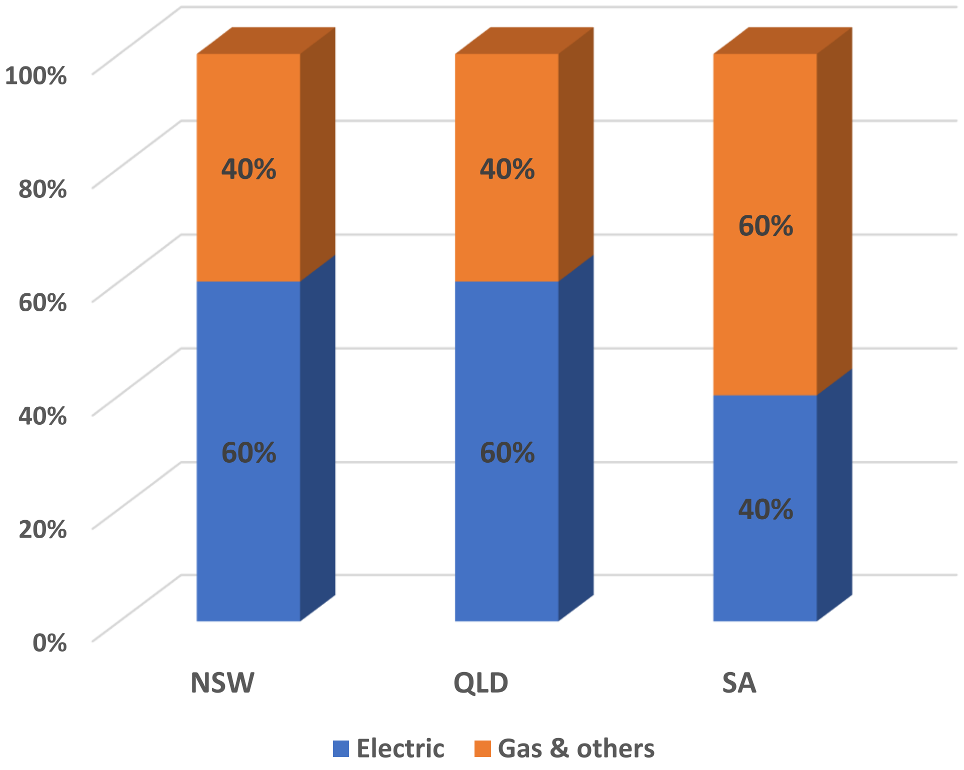
Project motivation: Energy Storage!

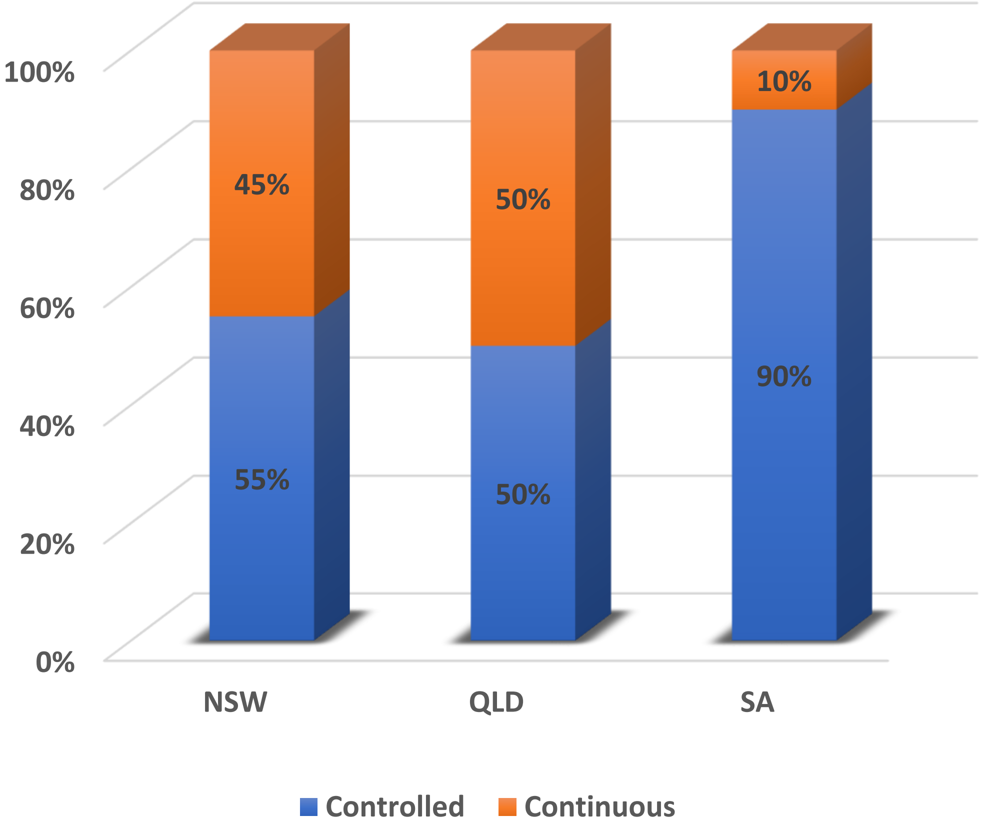
Home batteries vs. electric water heating storage tanks

- 13.5 kWh
- All electric applications
- ~$10,500 (including $2k battery rebate in NSW)
- ~ 250k households have a battery
- Typical lifetime 5-8 years
- Typical energy efficiency 85%-95%
- **Can utilize rooftop solar**

- 10 – 15 kWh (m x c x ΔT)
- Water heating only
- $1000 – $2000 (for a resistive system)
- **~4m households have storage tanks**
- Typical lifetime 10-15 years
- Typical energy efficiency 67-72%
- **Can utilize rooftop solar**

Project motivation: electric hot water system ownership and energy demand



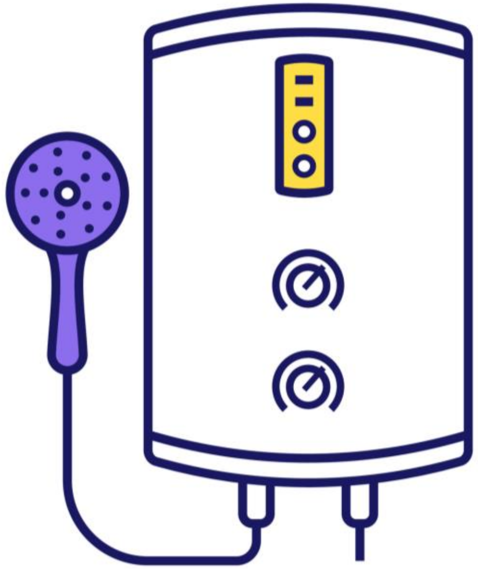


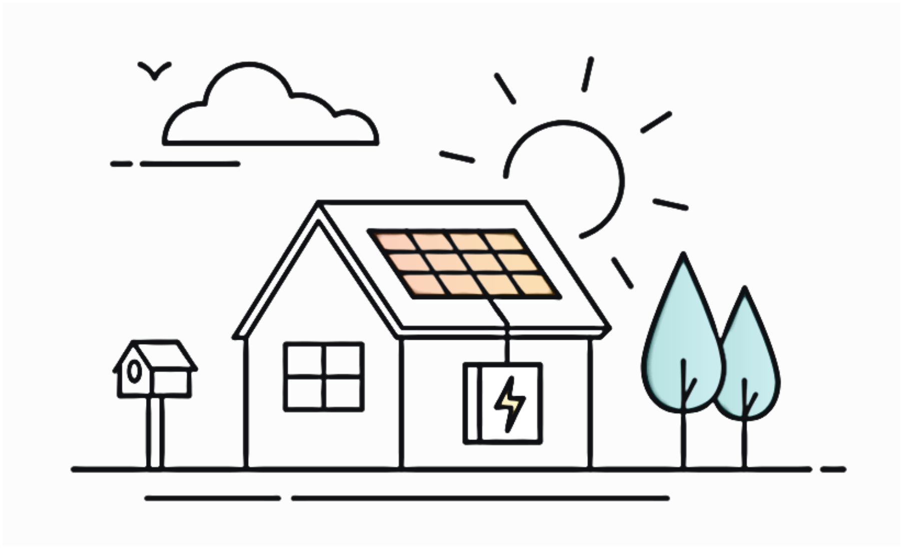
Between 25-30% of total residential energy use is attributed to water heating in Australia

Project motivation: smart meters

Currently between 30-40% of households own smart meters in Australia

Project Motivation: Control electric water heating systems via smart meters to soak-up solar





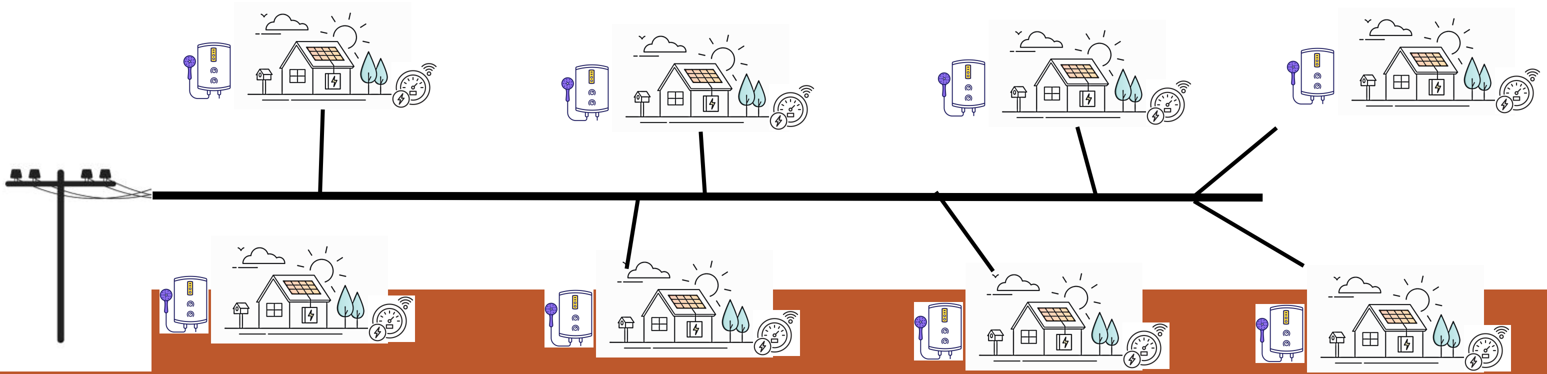


Image credits: Vecteezy, Solar Victoria, iStock

Part 2

1) Project motivation

2) Real-world trials:

- **South Australia PLUS ES Flexible Demand Trial (~20,000 households)**
- **Endeavour Energy Off-peak + Trial (~10,000 households)**

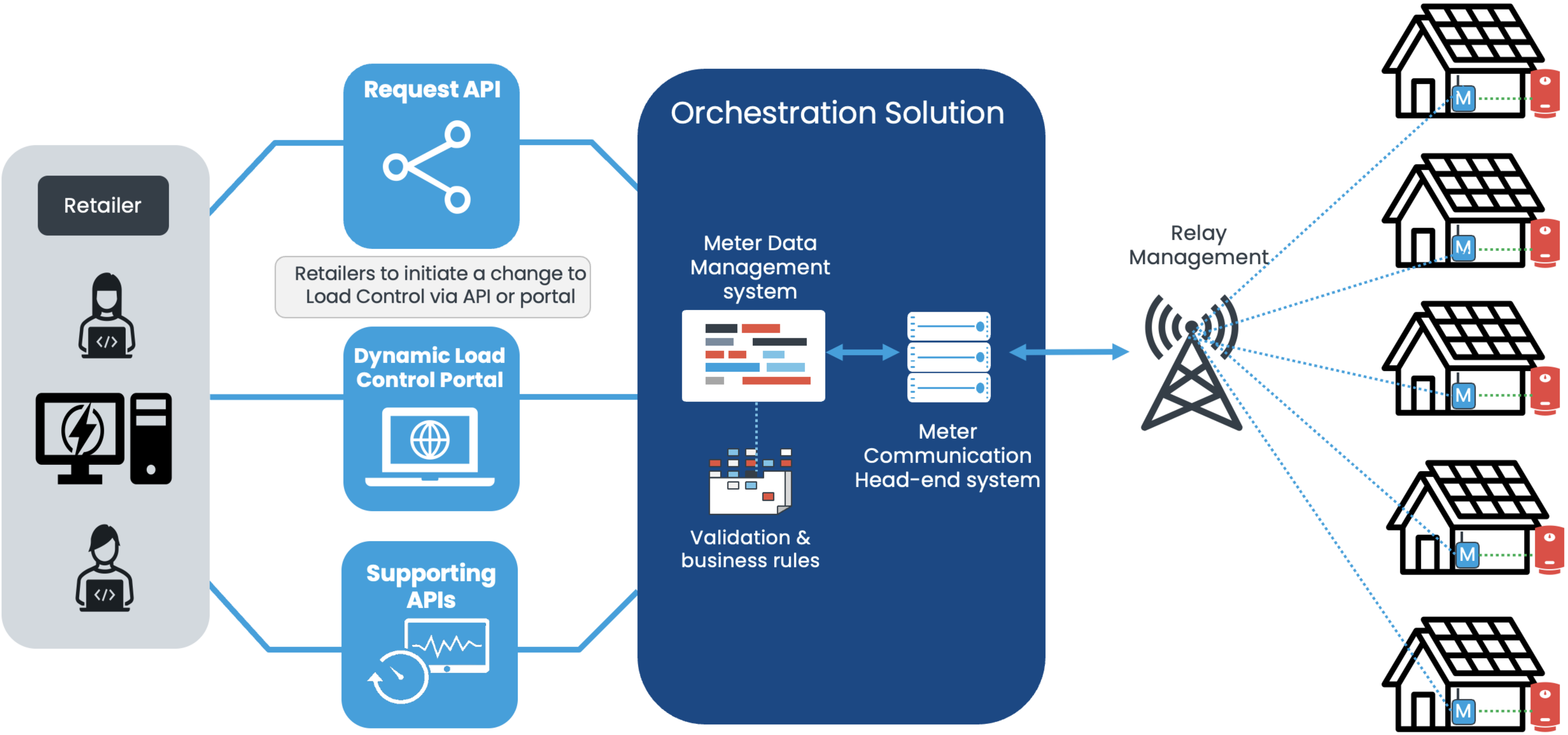
3) Network impact of electric water heating system coordination and control

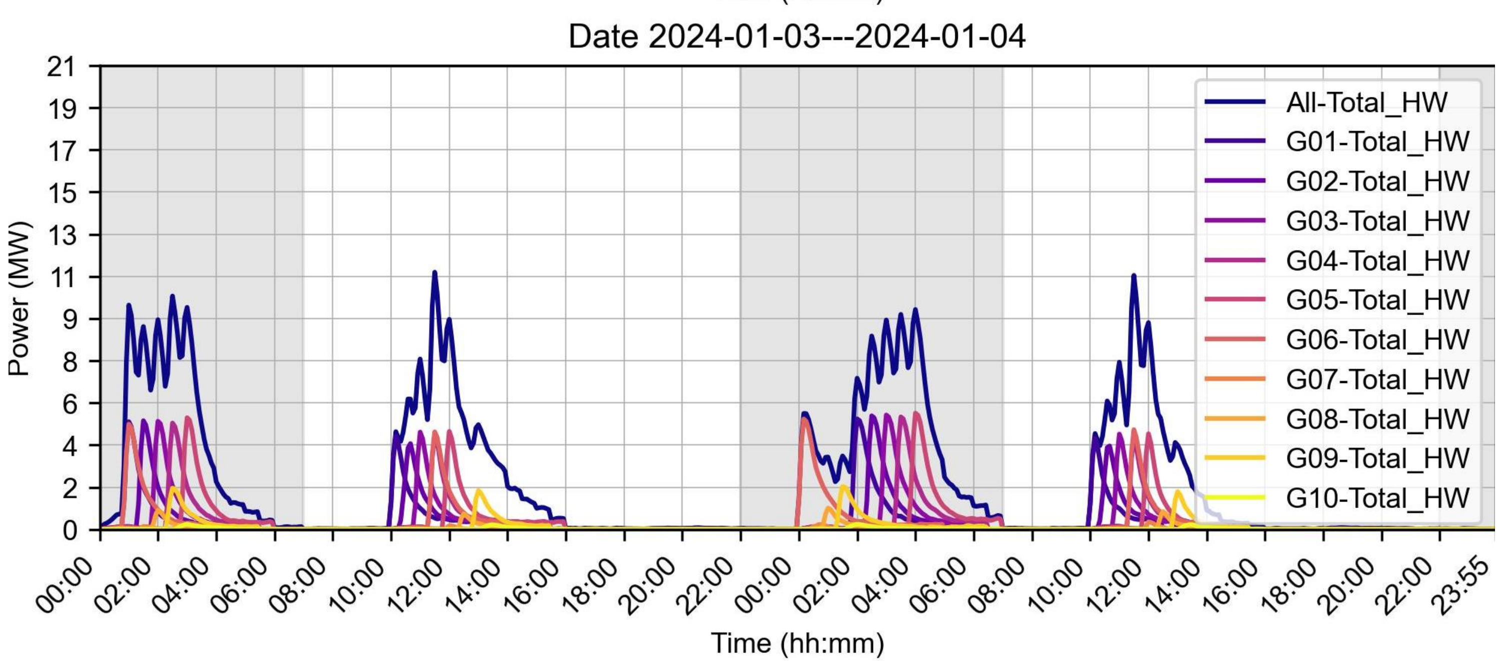
4) SolarShift Project Thermal Modelling Results

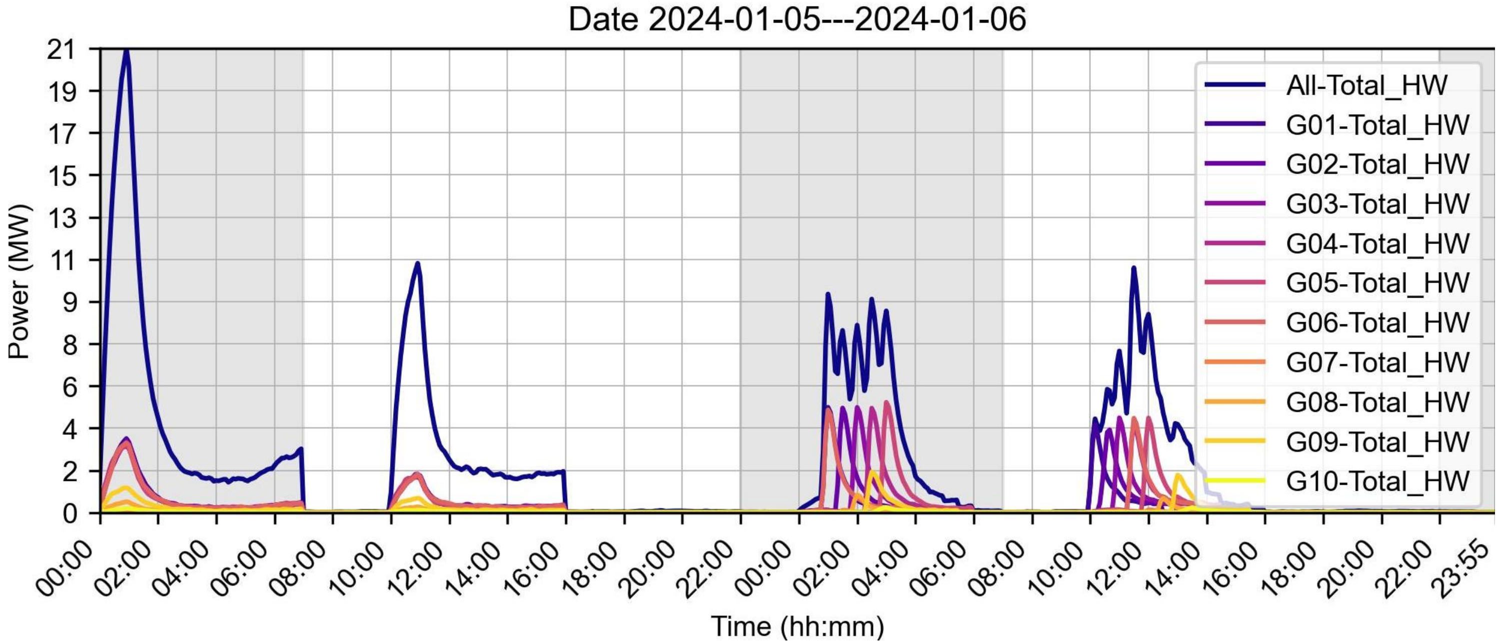
5) SolarShift Project Customer Hot Water Roadmap

6) Future research directions

South Australia (SA) Flex Demand Trial: Plus ES Smart meter control solution







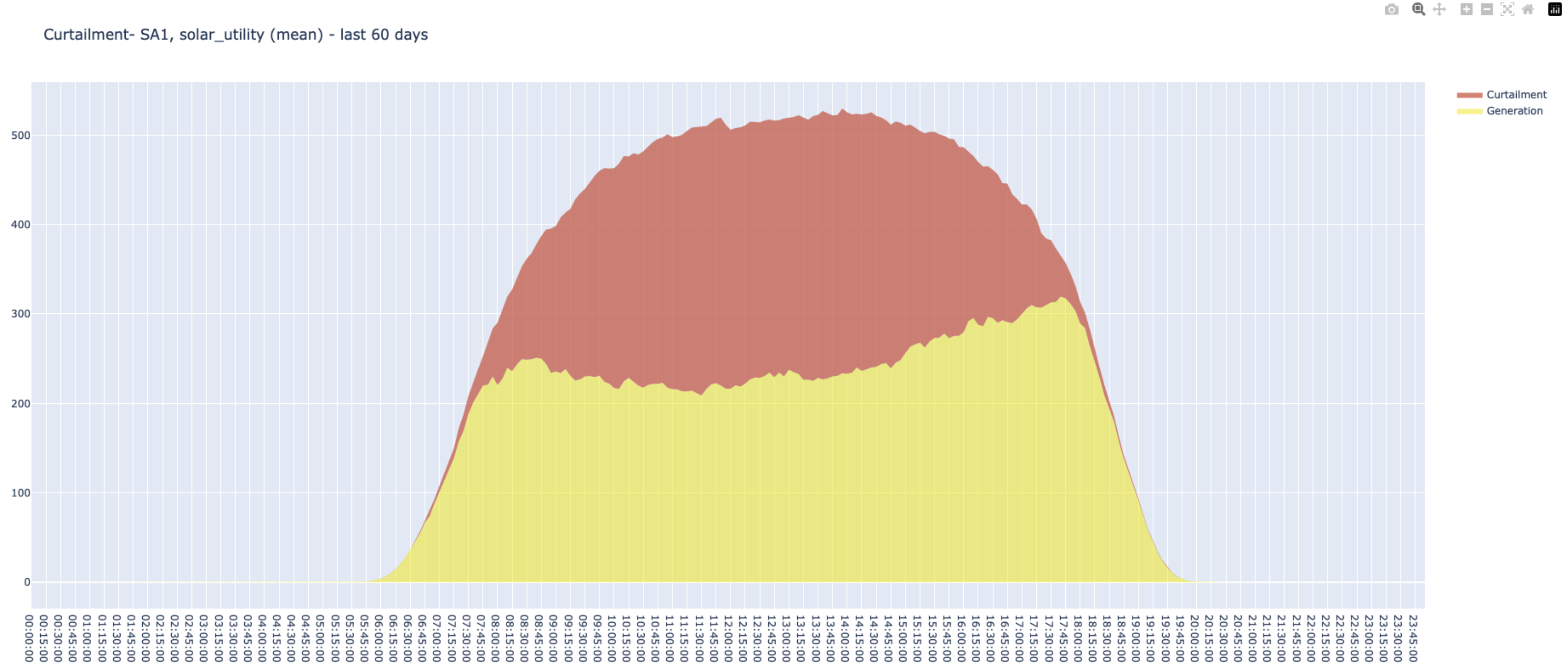
- Randomization between different groups decreased over the course of the trial:
  60 mins ➔30 min ➔15 mins
- There is also randomization within each group (5-10 minutes) depending on the size of group
- Dynamic scheduling considers wholesale market prices and temperature forecasts
- Static schedule applies the same shifting strategy across different days
- Default controlled load strategy (Controlled load, bottom left) causes demand peaks, other control strategies with refined randomization reduce the peak water heating demand

SA Flex Demand Trial: Hot water control

- ~20k households with controlled load in the trial with **smart meters**,
- However, ~25% of the controlled load circuits are inactive (this stat aligns with other states where 15-25% of controlled load fleet is inactive).
- On average **45.5%** of hot water load is shifted to daytime (~**50%** with Static 2 Control, latest control). On the individual household level: **0.9 MWh/year** and **2.5 kWh/day**. Shifted hot water energy during winter was almost twice of summer.
- If the implemented control can be successfully rolled out across the NEM, we estimate that there is on average **10.5 GWh** of **daily** flexible hot water load that can be shifted into solar generation periods.
- According to recent data from Australian Energy Market Operator (AEMO), there is an average of **6.3 GWh** of daily utility scale solar curtailment **(~11 GWh** including wind) over the last 12 months (fluctuates seasonally)!

Control strategy	Period	Mean daily DEWH load (MWh/day)	Mean daily DEWH load shifted to daytime (MWh/day)	Shifted (%)
Static 1	2023-07-01 to 2023-10-16	84.5	36.0	42.6%
Default CL2	2023-10-17 to 2023-11-08	68.4	27.2	39.8%
Dynamic	2023-11-09 to 2024-04-23	55.2	25.8	46.7%
Static 2	2024-04-24 to 2024-06-30	83.6	41.1	49.2%
Average	2023-07-01 to 2024-06-30	70	31.85	45.4%

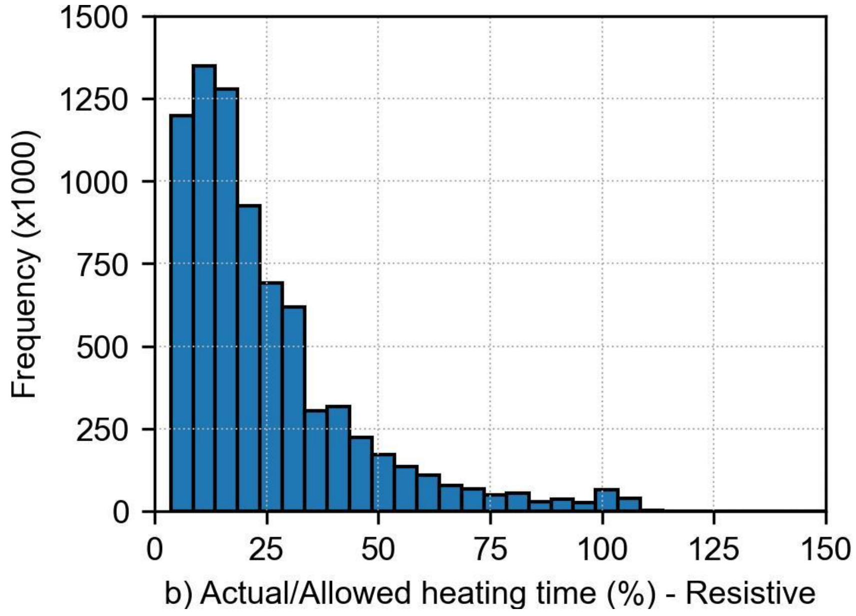
Solar curtailment vs. hot water demand

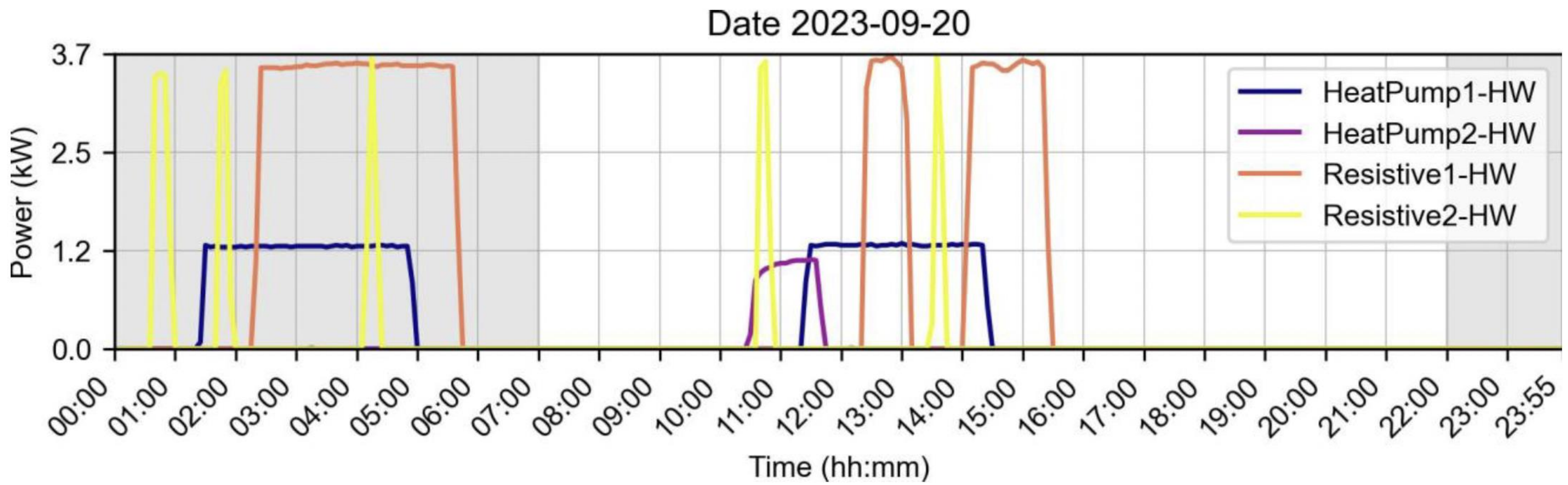


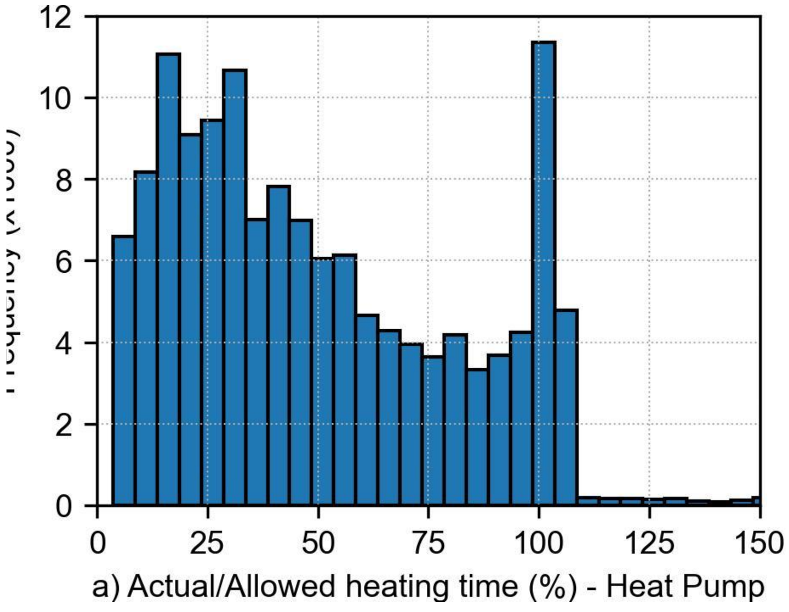
- There is an average of **6.3 GWh** of daily utility scale solar curtailment **(~11 GWh** including wind) over the last 12 months according to data from AEMO's website (fluctuates seasonally)
- Some solar farms loose **30-40% of daily generation**
- Successful roll out across the NEM: on average **10.5 GWh** of **daily** flexible hot water load that can be shifted into solar generation periods.

Heat-pumps

- Heat-pump manufacturers generally* don’t recommend external control of heat-pumps due to concerns regarding the compressor life-cycle.
- ~300 heat-pumps in the trial.
- Implemented control strategies generally work for heat-pumps but needs more refinement.
- With further improvements (checking ~0 power in the circuit before turning off, extra heating during winter), these concerns can be addressed.

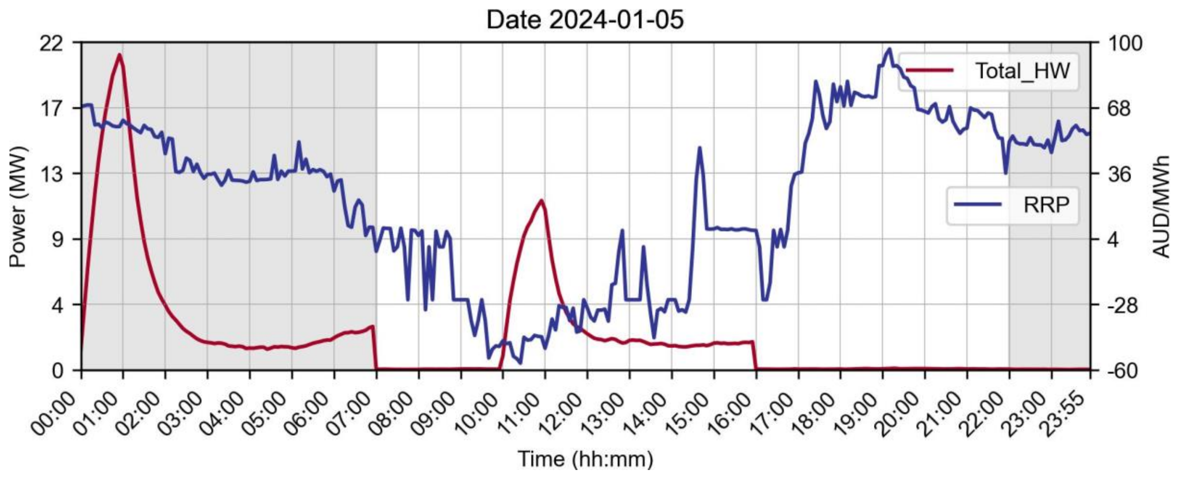


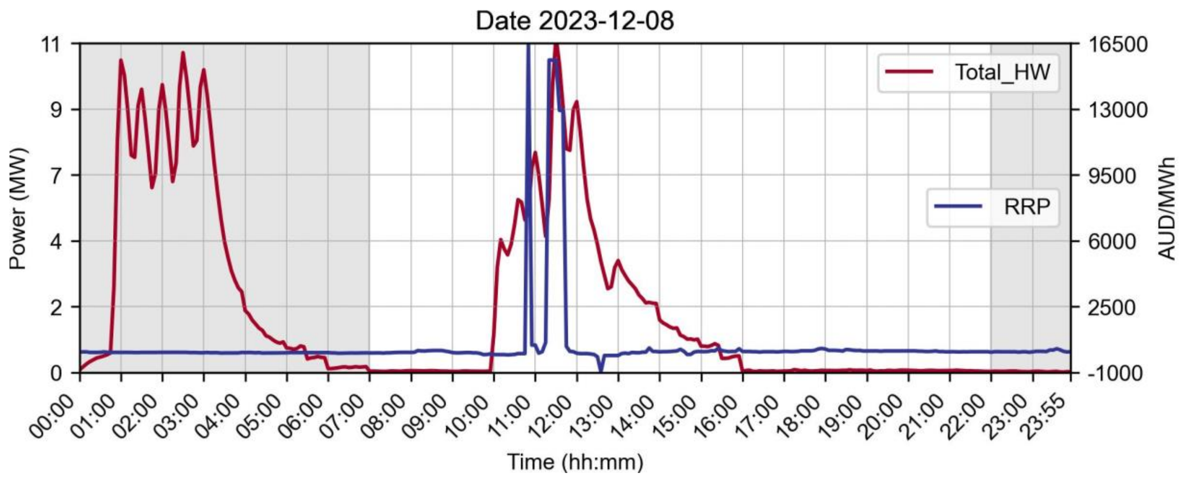




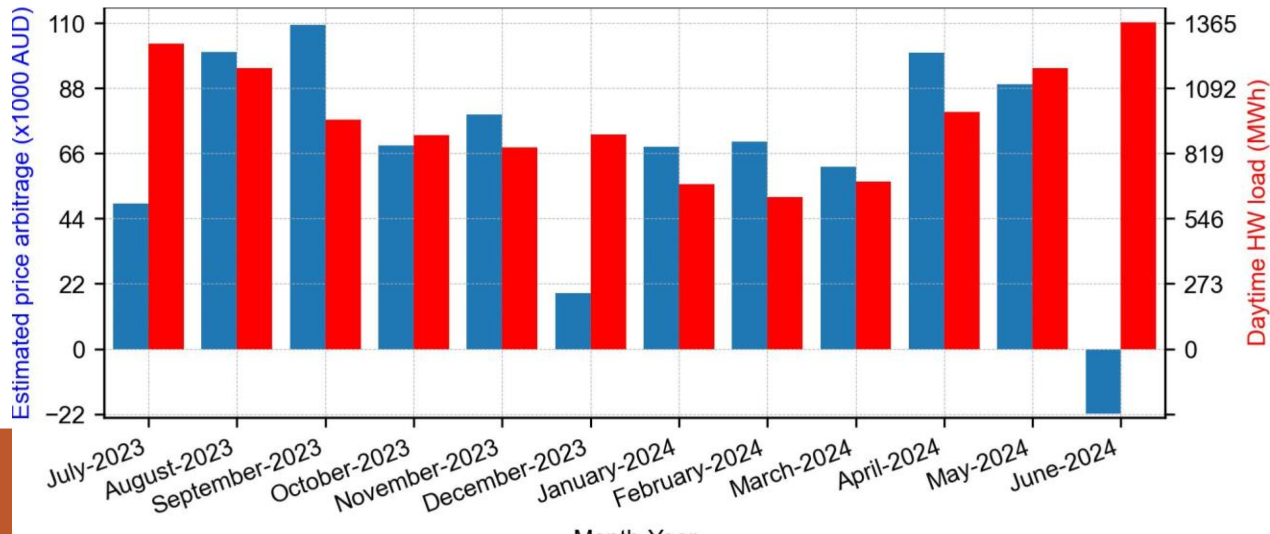
*Based on our conversations with 3 big heat-pump manufacturers in Australia

Financial savings & emissions reduction

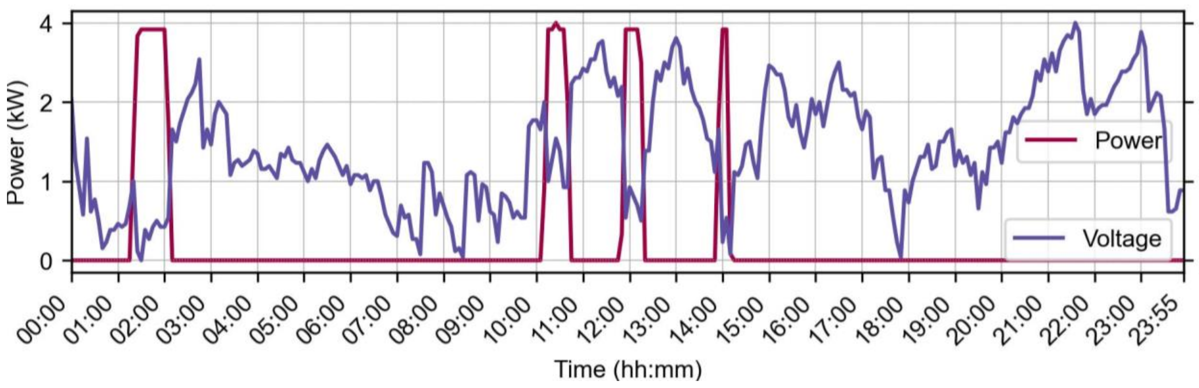


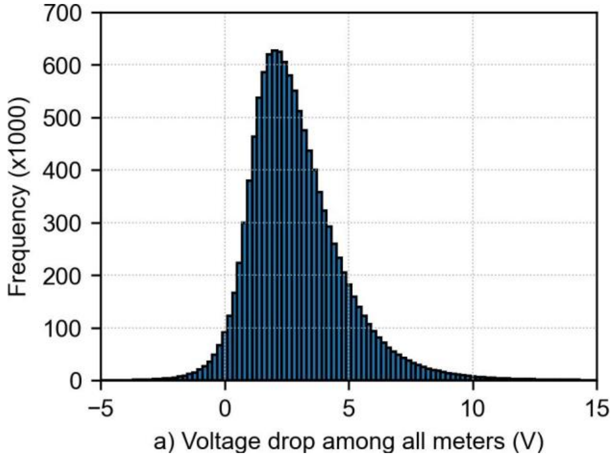


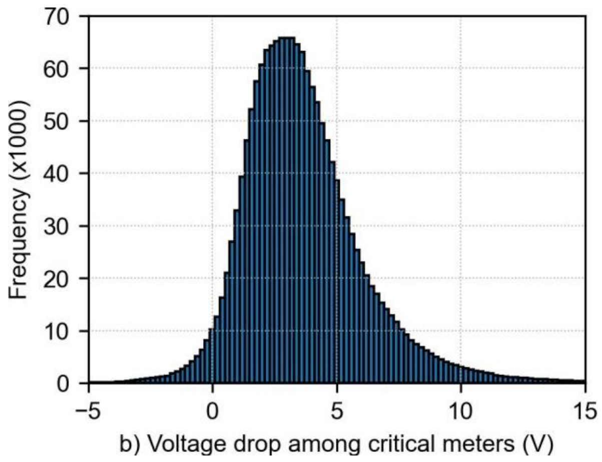
- $63/year savings from shifting hot water load
- Saving opportunity is likely to grow ➔ more renewables in the network ➔ lower day time prices & increasing number of resistive and heat-pump water heaters.
- **But these savings are currently are not passed onto households!** We need new tariffs if we want to incentivize households and have a larger controlled load/flex demand fleet.
- Trial operations reduced emissions associated with water heating by 14.3%! (depends on state & RE mix)
- Successfully roll out across the NEM ➔2.3 Mt-CO2/year reduction (8% of water heating emissions)



Voltage impact on the network



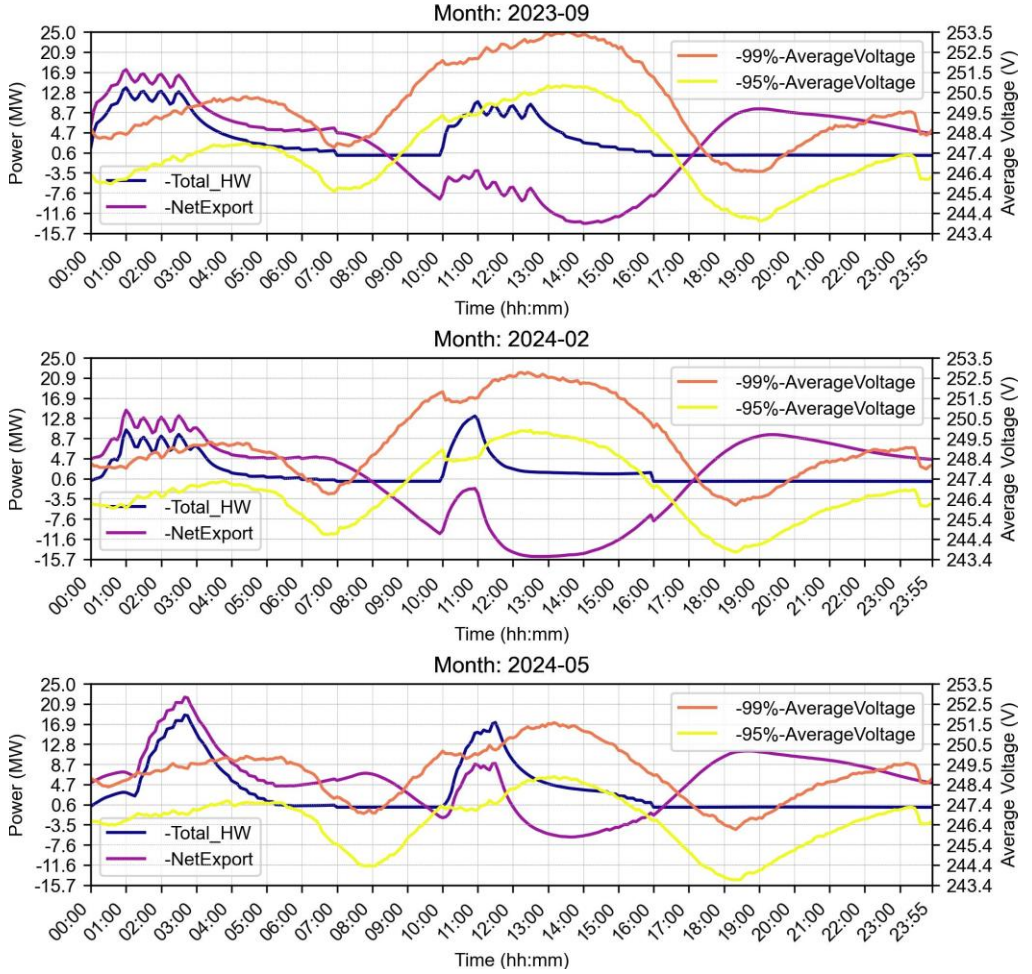




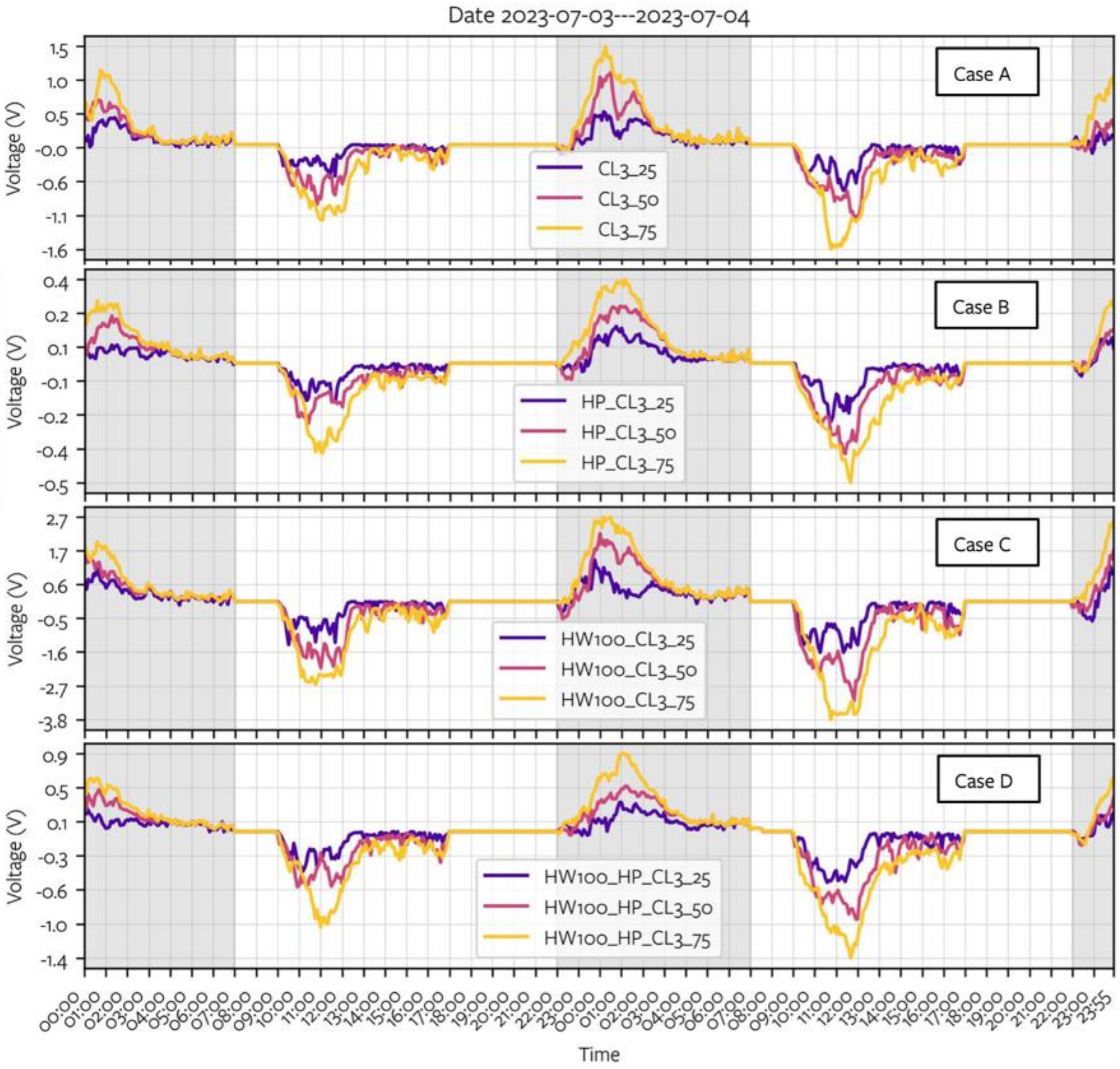
Median of 2.6V and a 95th percentile value of 6.4V

Median of 3.4 V and 95th percentile value of 8.2V

Entire fleet hot water, total export (from network) & voltages



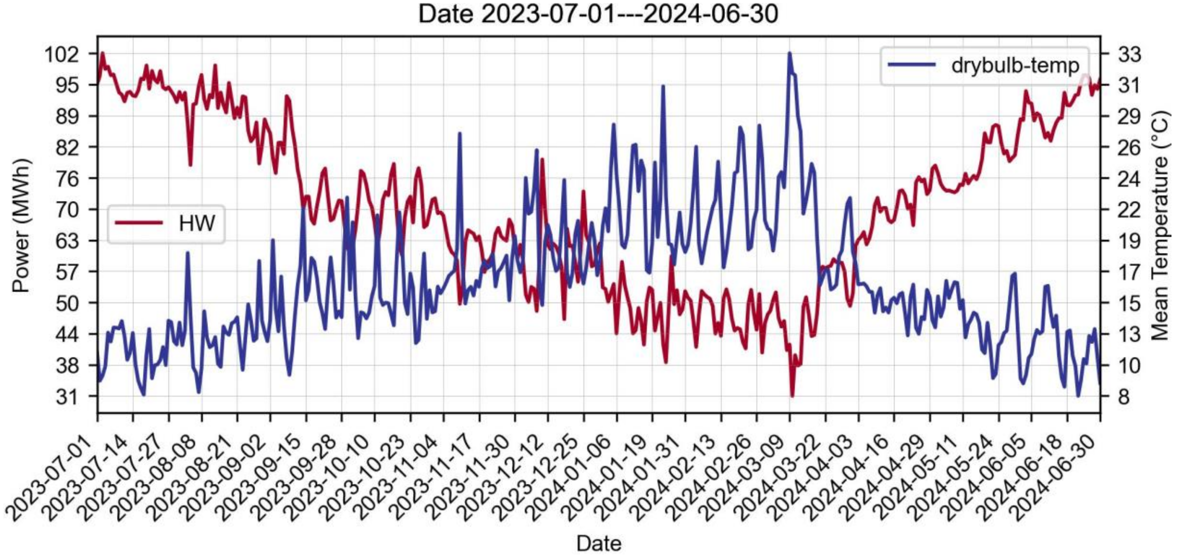
Impact on the network: Power flow modelling (Endeavour Energy trial)

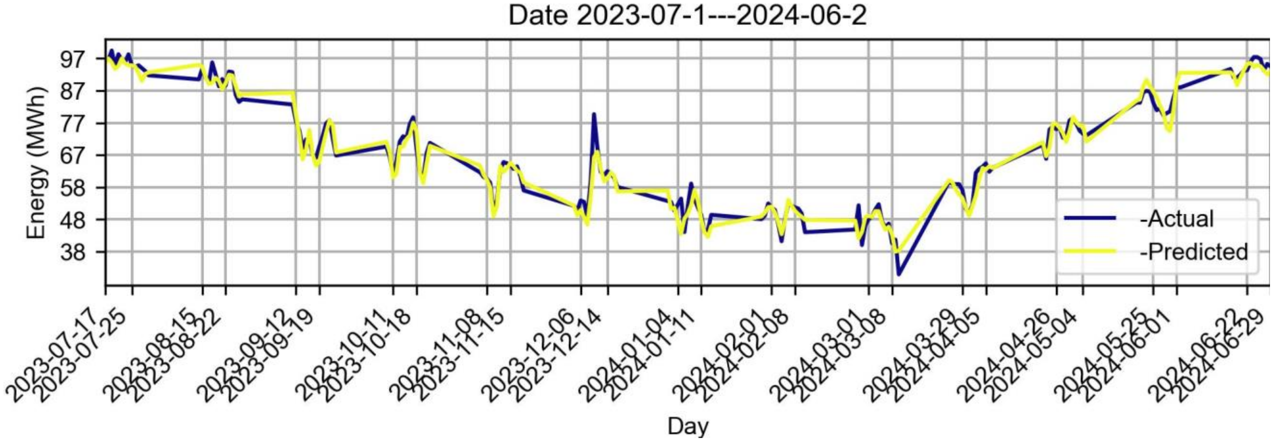


- Focus on a selected feeder with 109 households where 39 of them have electric water heating systems
- DIgSILENT power flow modelling of scenarios:
  - Case A: 31/109 resistive
  - Case B: 31/109 heat-pumps
  - Case C: 109/109 resistive
  - Case D: 109/109 heat-pumps
  - Different percentage of shifted load & control strategies
- Delta Voltage is the difference between the default CL1 (nighttime) voltages and the studied simulation
- Different solar ownership (future scenarios)
- We can improve strategies to use hot water as a potential voltage regulation service ➔ smooth and longer voltage drops along the feeder

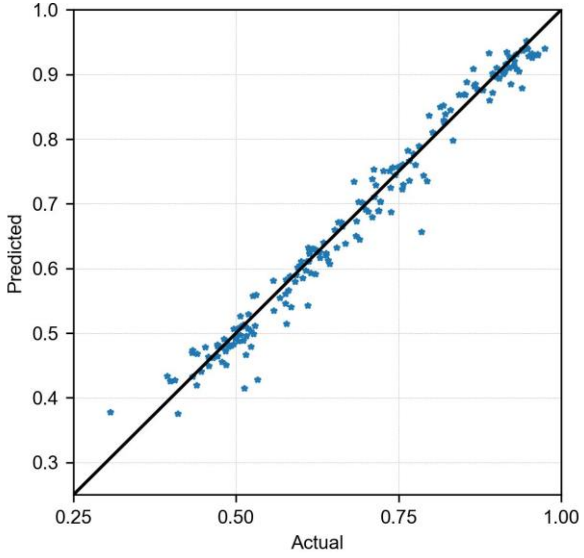
Forecasting day-ahead hot water electricity demand

High correlation with ambient temperature

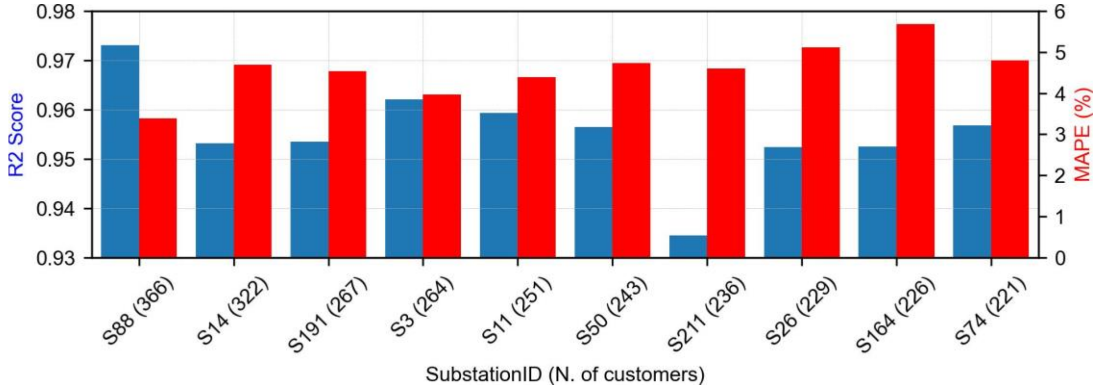




Entire fleet day ahead forecast
R2= 0.97 and MAPE = 3.19%



Accurate forecasts at the substation level



Customer survey results

- Out of the 18,843 customers participating in the trial, only 159 contacted AGL's customer service team to discuss or ask questions about the communications they received.
- Of these, 53 opted out of the trial, resulting in an opt-out rate of 0.3%.
- Most customer contacts occurred within the first few weeks after receiving the communications, with 85% of all interactions happening in the first two months.
- More detailed surveys were carried out after the trial
  - 70% of these post trial survey participants felt that the changes did not impact their comfort or convenience.
  - From the remainder of the participants who noticed changes told that the impact was minimal, not a noticeable change to their hot water service as long as they kept their routine

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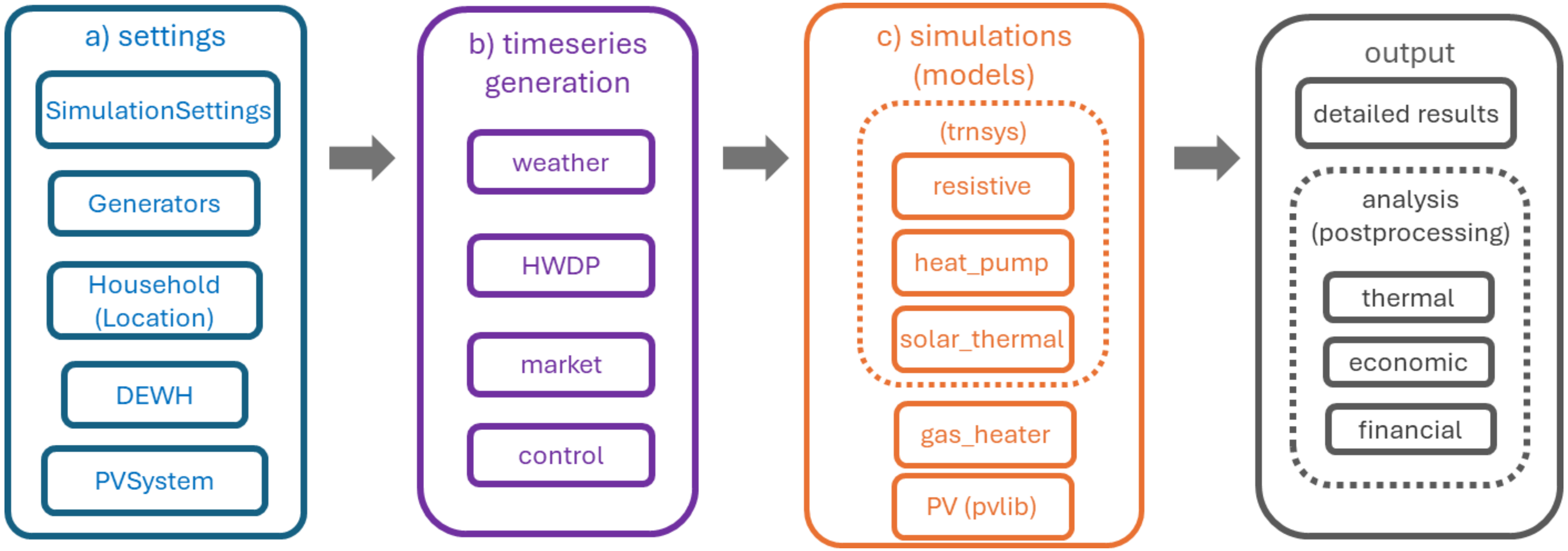
5) Contributions & future research directions

SolarShift: Thermal modelling of water heating systems

- Open-source repository based on Python/TRNSYS.
- Available in: github.com/UNSW-CEEM/tm_solarshift.



SolarShift: Thermal modelling

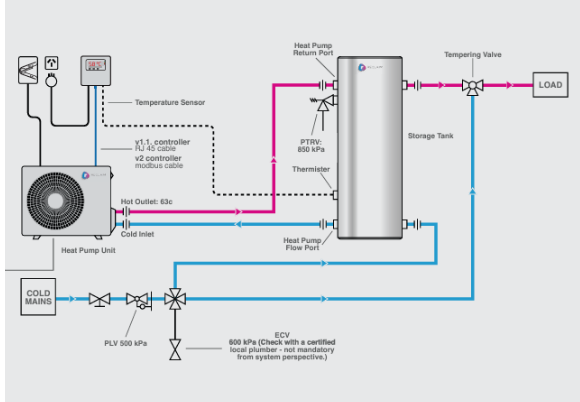
PV System:
- 5kW generic installation.
- pvlib's ADR method.

- Different climate regions
- Different number of people
- Network and retail tariffs

Resistive Heater

- Rheem 492 series (80-400L).
- Model: Trnsys.

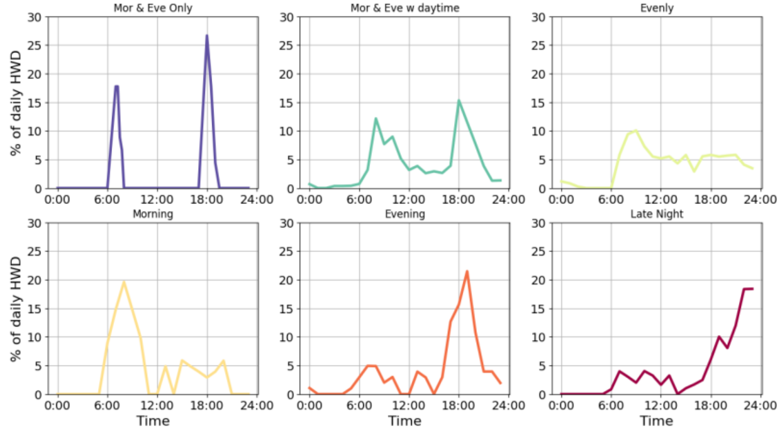
Heat pumps:



- Reclaim energy glass lined systems (160-400 L).
- Model: Trnsys.

(Reclaim Energy)

Hot water draw profile



Gas heater instantaneous

- Rheem gas continuous flow 12-26L.
- Model: Python.

Gas heater with storage

- Rheem 4 Star (90L – 170L).
- Model: hybrid.

Solar thermal collector

- Rheem Loline, electric booster (270-410 L).
- Model: Hybrid.

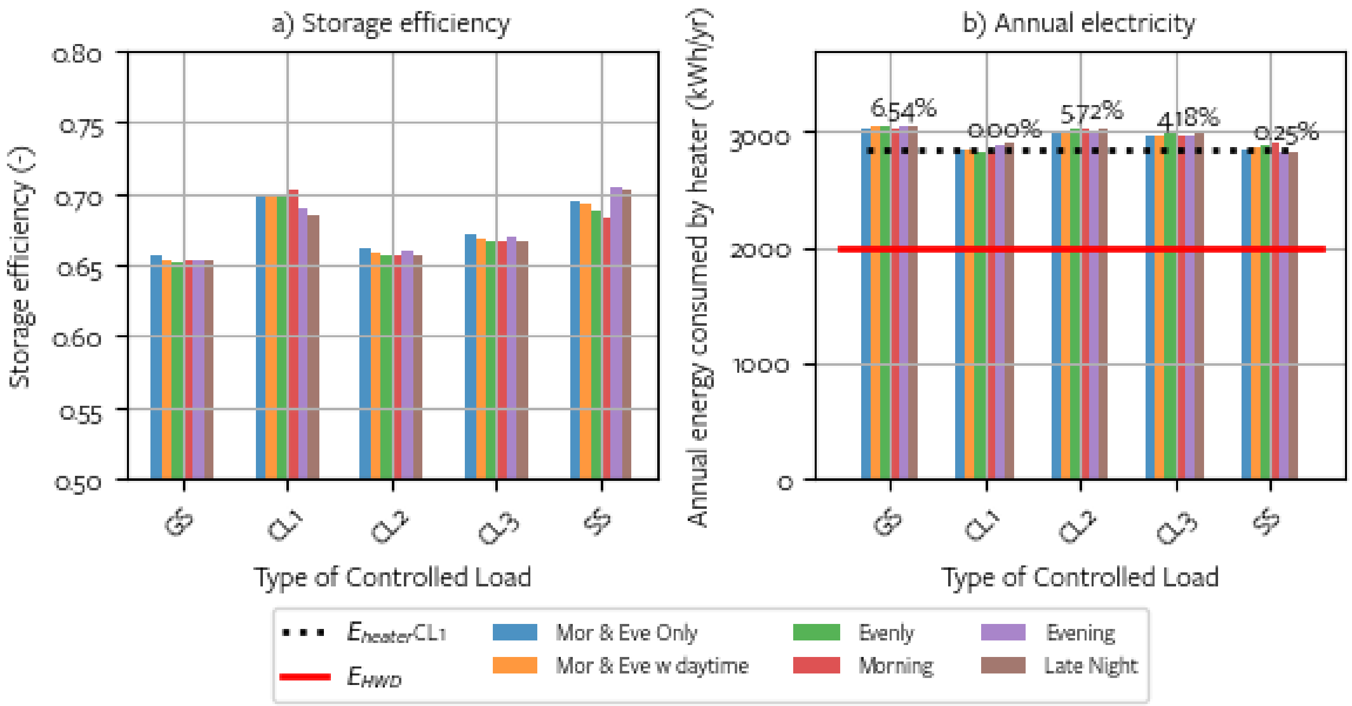
Control strategies

Three controlled loads from Ausgrid's ES7 Network Price Guide:

- **CL1**: nighttime (typically 10 pm-7am).
- **CL2**: all time, except evening peak.
- **'CL3'**: new Ausgrid's solar soak (CL1 + solar window)
- **GS**: 24/7 general supply.
- **SS**: only solar soak (9am-3pm).

SolarShift: Thermal modelling performance of water storage tanks

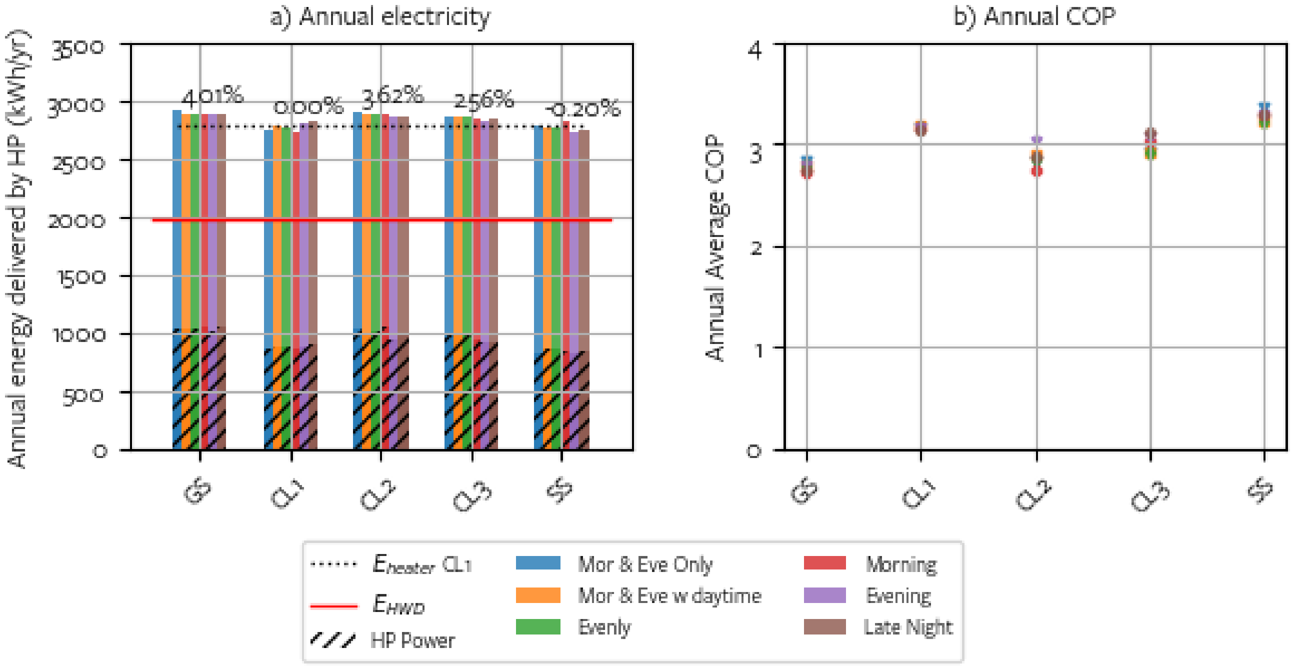
- TRNSYS modelling showed that average storage efficiency is between **67-72%** for standard storage tanks (base case Sydney with 4 people household)
- **1/3rd of energy is lost ambient from the tanks (average Australian household uses is 6kWh of electricity to heat water, 2kWh of is lost to ambient!)**
  - **2 TWh/year across NEM (~1% of total electricity consumption**
  - This can represent more than 10%-15% of annual electricity bills (depends on tariffs and usage)

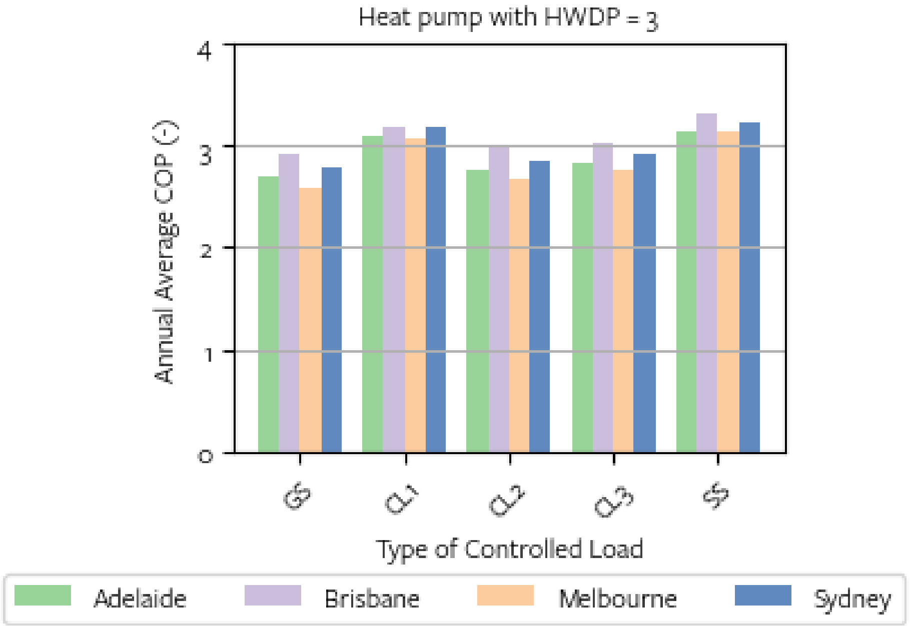


Thermal performance and losses from water tanks

- Our minimum energy performance standards for water storage tanks **AS/NZS 4692 is from 2005**
  - The standard allows large heat losses from the tanks
  - Energy landscape has rapidly changed over the last decades including tariffs, energy offers, consumer energy resources etc.
  - It may be time to revisit these standards and consider what level of heat loss is acceptable!
- Reducing heat loss coefficient by half through improved insulation 15% savings in costs and emissions associated with water heating
- A detailed cost benefit analysis is yet to be undertaken:
  - What is the financial implications of improved insulation for manufacturers and consumers?
  - How difficult is it to change existing tank manufacturing?

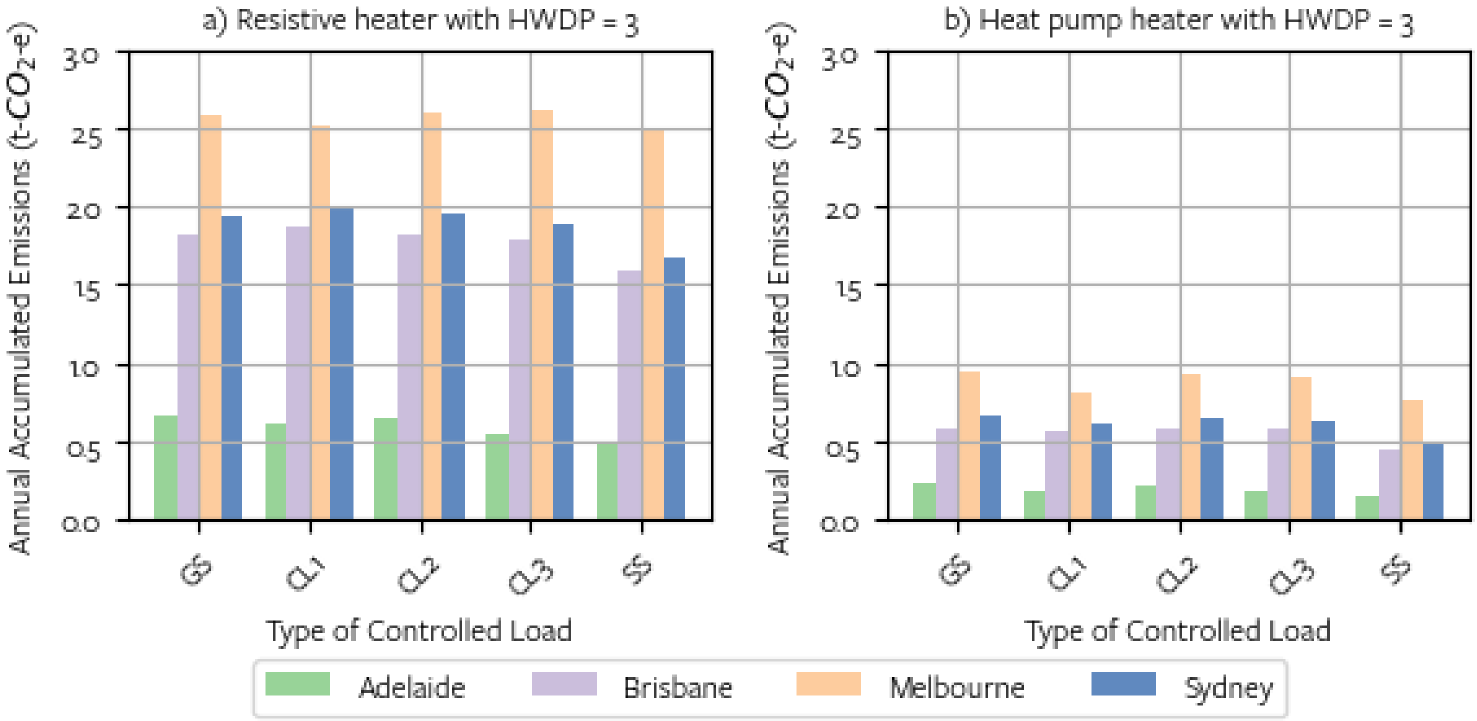
Heat pump thermal modelling





- Hot water energy consumption is reduced by two-thirds compared to resistive heaters.
- An average COP ranging between 2.7 and 3.4 is observed (COP_{design} = 6.02).
- The annual COP is both impacted by the climate and control type (in some cases the latter has a larger impact).
- Annual COP is comparable on different cities.

Annual emissions from water heating

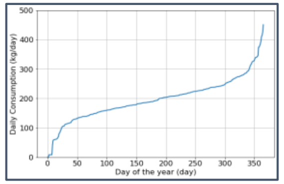


- There is a 67% reduction on average when switching from resistive heater to heat pumps.
- The NEM region plays an important role: Adelaide has 20% of Melbourne emissions.
- Solar soak control offers better results in all cities. 17% reduction from moving from CL1 to SS in Sydney.

MonteCarlo Simulations

- Most tanks don’t have thermo-couples, flow meters or data loggers to monitor the temperature or water flow
- How to predict the “shiftable” thermal capacity a day ahead **at the individual site level?.**
- Estimate the **hot water shortage risk** in certain conditions (what happens when your family and friends come for an extended visit?)
- Simulate a set of “typical” days and check the output distributions

HWD generator



Parameter	Dish/cloth. wash.	Shower	Bath	Sink
DHW vol/day(l)	72	80	20	28
Flow rate (lpm)	6	8.0	14	1
Duration (min)	1	5	10	1
Events per day	12	2	0.14	28

intra-day dist.

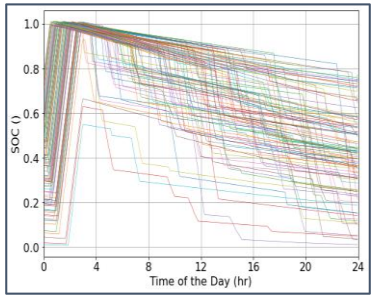
inter-day dist.

events description
(Fuentes et al., 2018)

Other generators

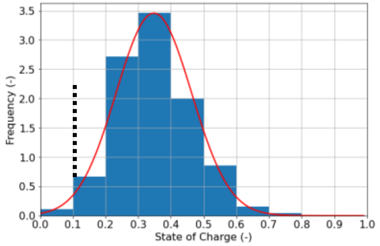
- Weather: selecting days (randomly) from data.
- Control: randomization in CL scenarios.

MC simulation

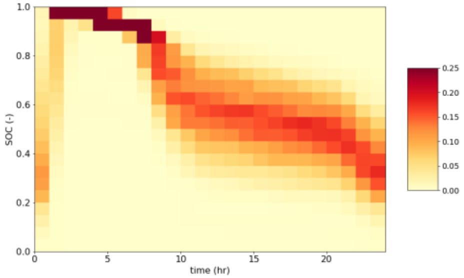


- N simulated days.
- days are generated statistically.
- outputs: probability function of variables of interest

output



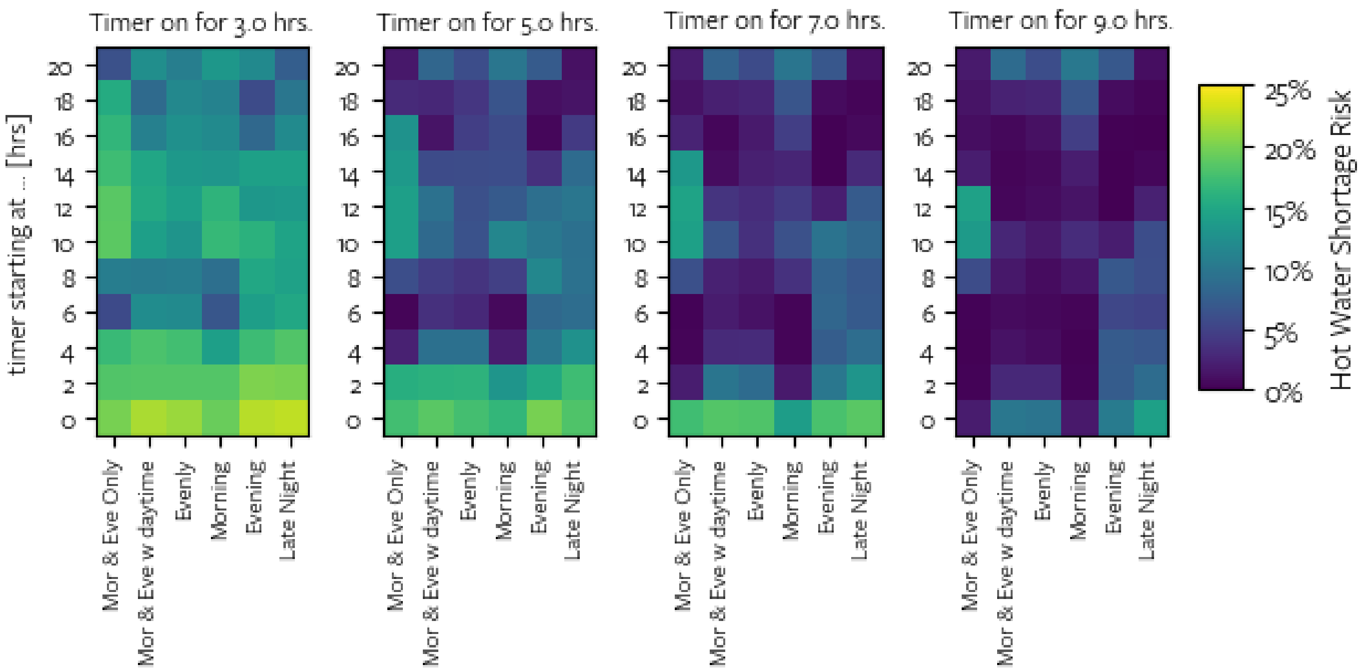
SOC at the end of day



SOC heatmap through the day

Risk of running out of hot water

- Monte-Carlo simulations to test the state of charge of the tank under different consumption, control strategies and weather patterns (hot water shortage risk SOC<=10%)
- Certain hot water draw profiles (HWDP) create more predictable state of charge (SOC) for the tank under different usage circumstances.
- Hot water shortage risk depends on the alignment between heating times and HWDP.
    - Shifting entire water heating to solar-soak period has risks of running out of hot water for certain consumption cases
    - **Including hot water heating windows in early morning and late afternoons significantly reduces the risk of running out of hot water**



Today's content

1) Project motivation

2) Real-world trials:

- South Australia PLUS ES Flexible Demand Trial
- Endeavour Energy Off-peak + Trial

3) SolarShift Project Thermal Modelling Results

4) SolarShift Project Customer Hot Water Roadmap

5) Contributions & future research directions

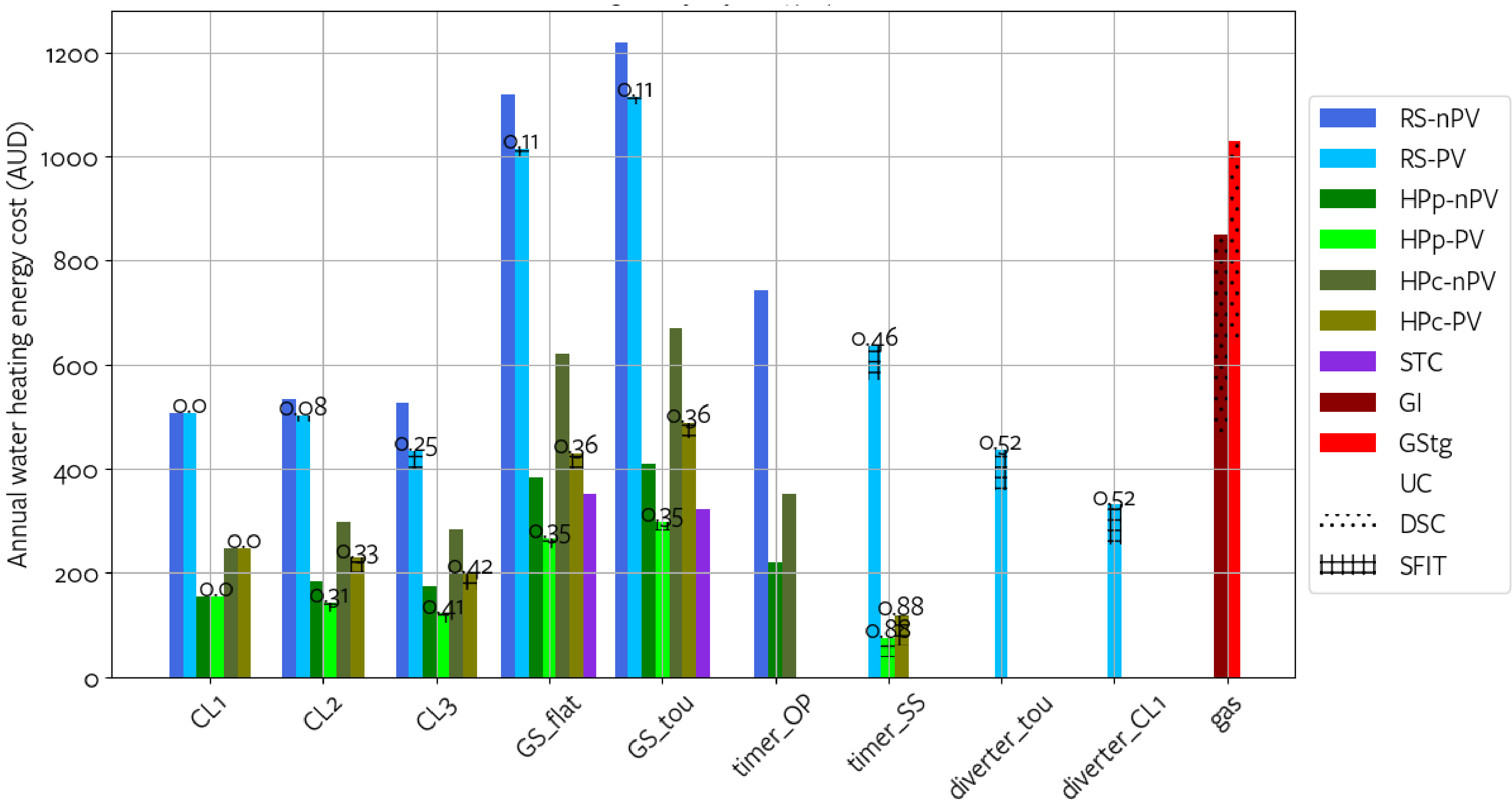
4) SolarShift: Customer Hot Water Roadmap

- Hot water technology (resistive, heat-pump, solar thermal, gas), including PV solar-soak options (timers, diverters)
- Controlled load strategies (CL1, CL2, CL3, SS)
- Hot water draw profiles (HWDP)
- Number of people (1-5+)
- Climate (capital cities)
- PV ownership
- Tariffs and rebates (if applicable)

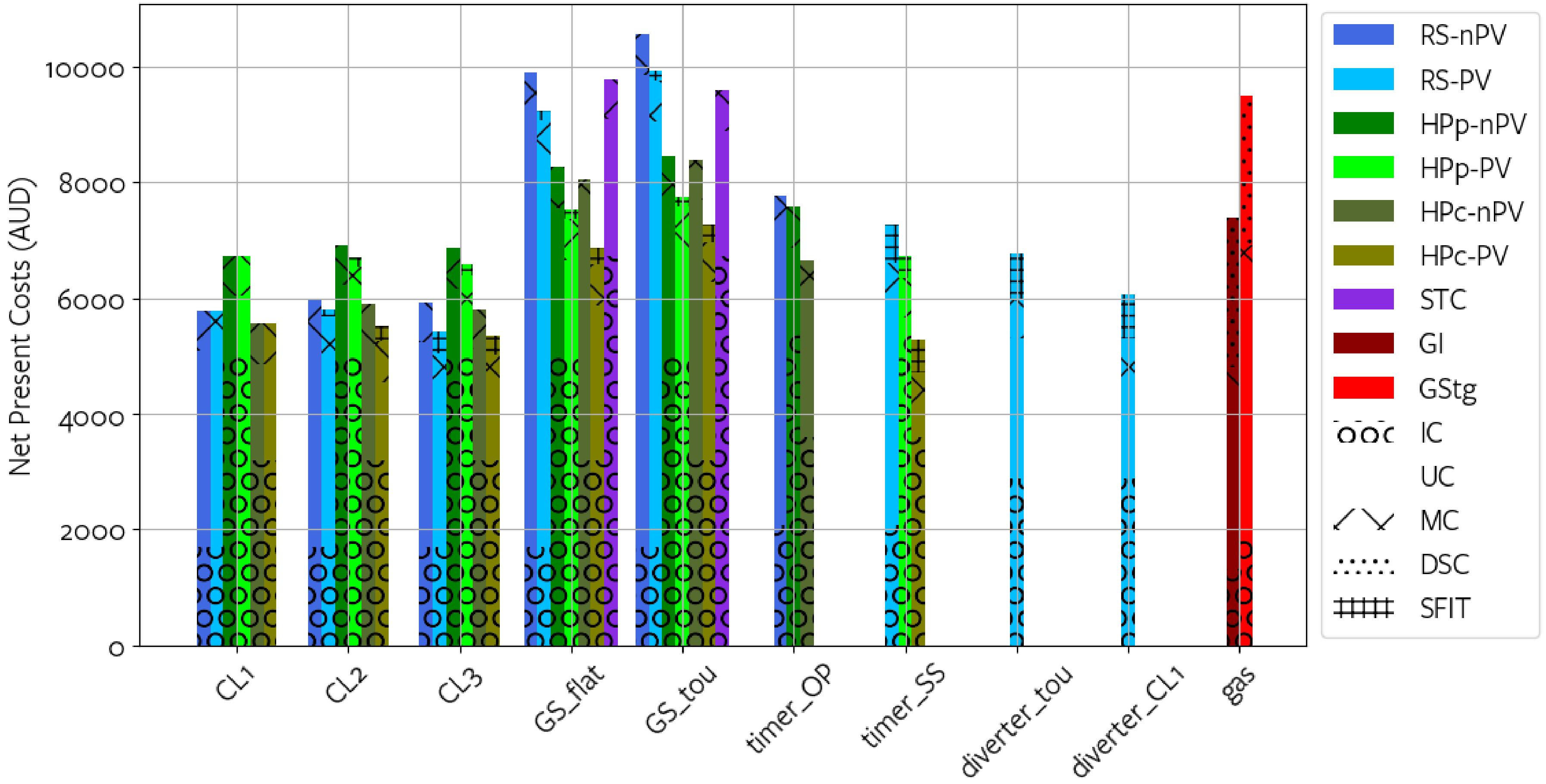
➢ Annual electricity bills
➢ Net present costs
➢ Pay-back period

➢ The roadmap will be turned into an online public tool to empower households when making decisions about their water heating systems

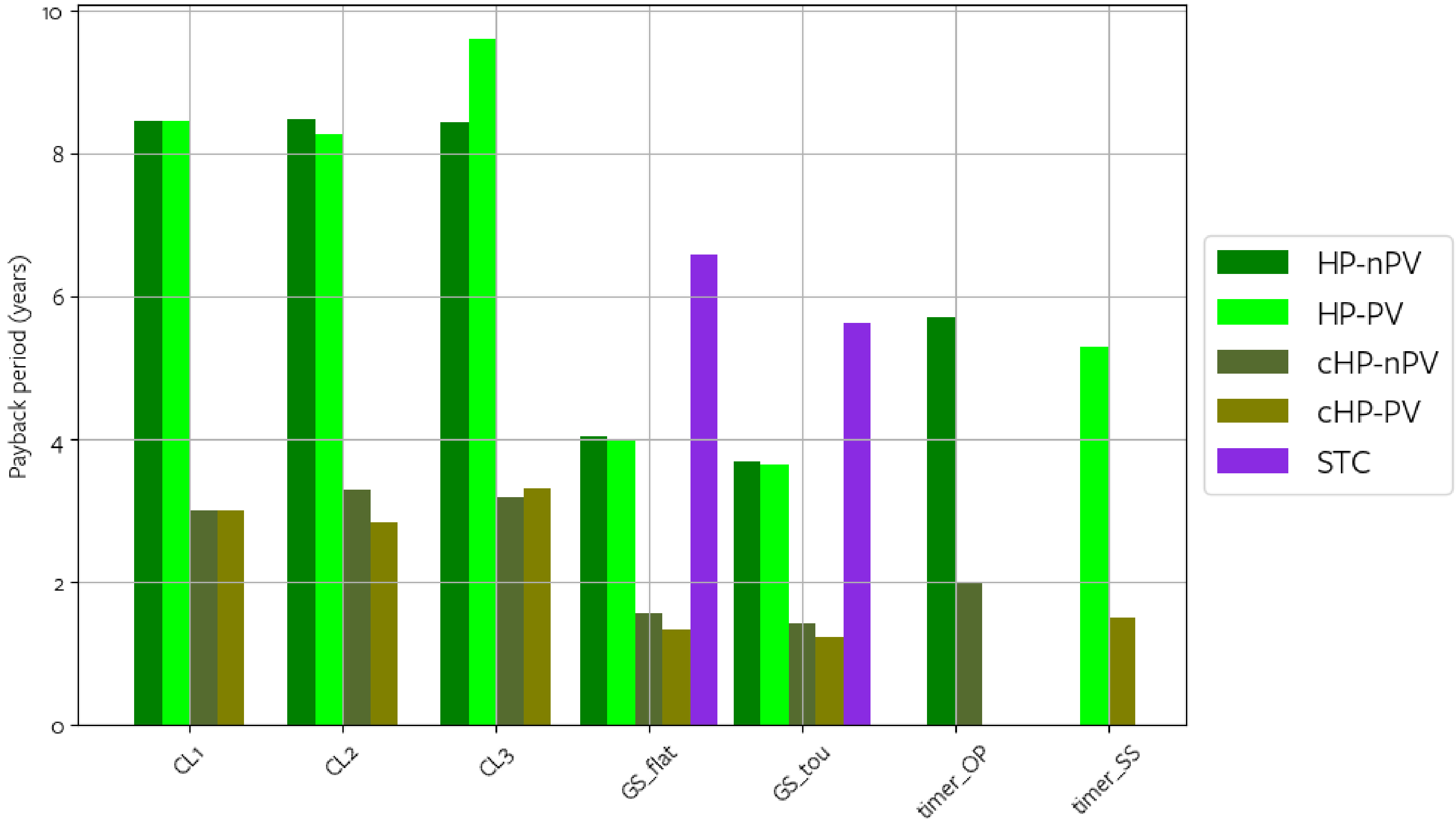
Annual water heating bill



Net present cost

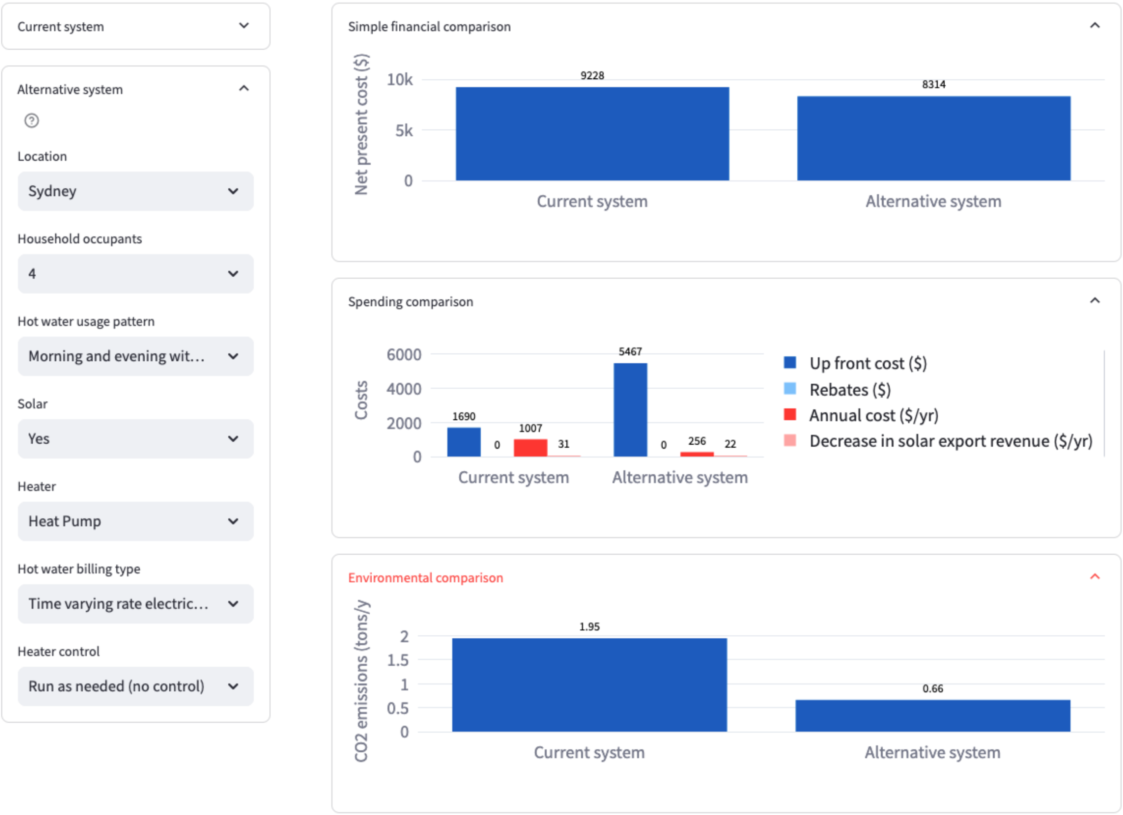


Payback period



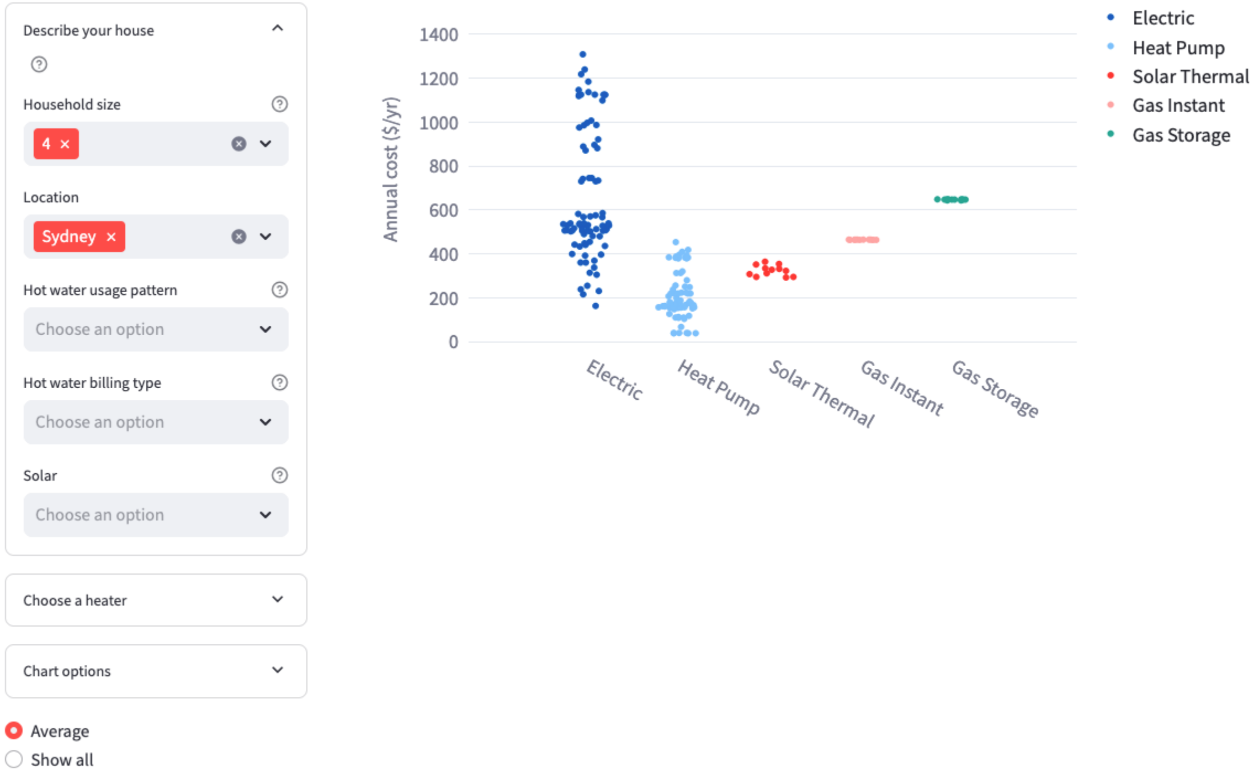
Customer Hot Water Roadmap: Online tool

Compare two hot water systems in detail



Explore hot water system configurations

The chart below can display many hot water simulation results at once – use the options on the left to explore the results.



Heater	Net present cost ($)	Up front cost ($)	Rebates ($)	Annual cost ($/yr)	Decrease in solar export revenue ($/yr)	CO2 emissions (tons/yr)	Annual energy consumption (kV
Electric	7181.04	1847.14	0.00	653.85	23.24	1.95	2966
Gas Instant	7874.35	1322.00	0.00	463.86	0.00	0.54	Nc
Heat Pump	7998.82	5467.00	0.00	205.29	8.71	0.63	961
Gas Storage	9578.47	1885.00	0.00	646.53	0.00	0.85	4015
Solar Thermal	10009.31	6740.00	0.00	323.35	0.00	0.63	927

https://solar-shift.streamlit.app/

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On media

UNSW study: channelling rooftop PV into water heating is a residential super saver

Put solar in your hot water tank! Off-peak electricity rates are fast becoming an unhelpful price signal for rooftop solar owners, who benefit by self consuming their excess solar ahead of drawing electricity from the grid at any time of day.

SEPTEMBER 6, 2021 NATALIE FILATOFF

DISTRIBUTED STORAGE | ENERGY MANAGEMENT SYSTEMS | ENERGY STORAGE | ENERGY STORAGE | MARKETS | MARKETS & POLICY | AUSTRALIA

Love is a hot shower at the lowest possible cost. A new study by UNSW shows it's worth pouring some excess PV into it.

Image: pv magazine Australia

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UNSW > News > 04 > UNSW leads thermal battery research at RACE for 2030

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UNSW leads thermal battery research at RACE for 2030

UNSW's new SolarShift project, led by the School of Photovoltaic and Renewable Energy Engineering (SPREE) will coordinate and operate about 3,000 domestic electric water heaters as a giant, 'Megawatt scale' thermal battery to soak up excess solar generation and support electricity networks.

Published on the 11 April 2023

THE CONVERSATION

Academic rigour, journalistic flair

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If our hot water heaters ran off daytime solar, we would slash emissions and soak up cheap energy

Published: November 14, 2024 12.41pm AEDT

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RENEW ECONOMY

CLEAN ENERGY NEWS AND ANALYSIS

Tuesday, June 3, 2025

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Home » Smart Energy » Electric hot water is a hero of flexible demand. Where does it stand in the age of rooftop solar?

Electric hot water is a hero of flexible demand. Where does it stand in the age of rooftop solar?

Image: Rheem

Baran Yildiz Oct 31, 2023

Policy and industry impact

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Home / News Centre / Media Releases / Pilot to policy research crucial to energy transformation

Pilot to policy research crucial to energy transformation

31 January 2023

The Australian Energy Market Commission (AEMC) is calling on Australia's brightest academics to collaborate with the rule-maker to develop more 'pilot-to-policy' approaches to ensure their research contributes quickly and effectively to the energy transformation.

In a keynote speech delivered to the ERICA - State of Energy Research Conference at UTS today, the AEMC's Chief Executive Benn Barr, claimed the greatest gains the next decade of research can offer might not be in technology, but in the 'missing link' between trials and deployment.

"The energy sector has to move fast. Governments across Australia are largely aligned and keen to act. This means the most successful research projects of any kind in the next decade will have their transition to policy 'baked in' from the start," he said.

Mr Barr cited the UNSW SolarShift project, which looked at turning household electric hot water heaters into mega batteries, as an example of the close relationship between research and rule-making. He said the work informed a rule change by the AEMC in 2021, allowing greater integration of innovative storage into the National Energy Market (NEM).

- Informing **Australian Energy Market Commission (AEMC) rule change** on flexible trading arrangements through quantifying potential financial and environmental benefits of the flexible demand of electric water heating systems
- Industry consultations processes & invited speaker:
  - Energy Efficiency Council
  - AEMC
  - Rheem
  - Stiebel-Eltron
  - AGL
  - Smart Energy Council
  - NSW Decarbonization Innovation Hub
  - ANU Centre for Energy Systems

Project outputs

RACE for 2030
RELIABLE AFFORDABLE CLEAN ENERGY

Final report

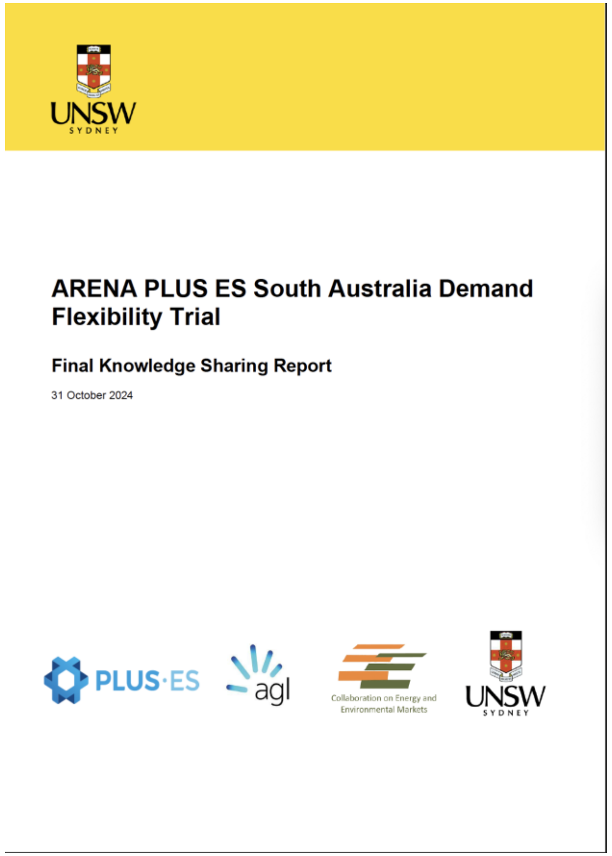
SolarShift

Turning household water heating systems into MW batteries

February 2025

Australian Government Department of Industry, Science and Resources | Cooperative Research Centres Program

[SolarShift Final Report]



UNSW SYDNEY

ARENA PLUS ES South Australia Demand Flexibility Trial

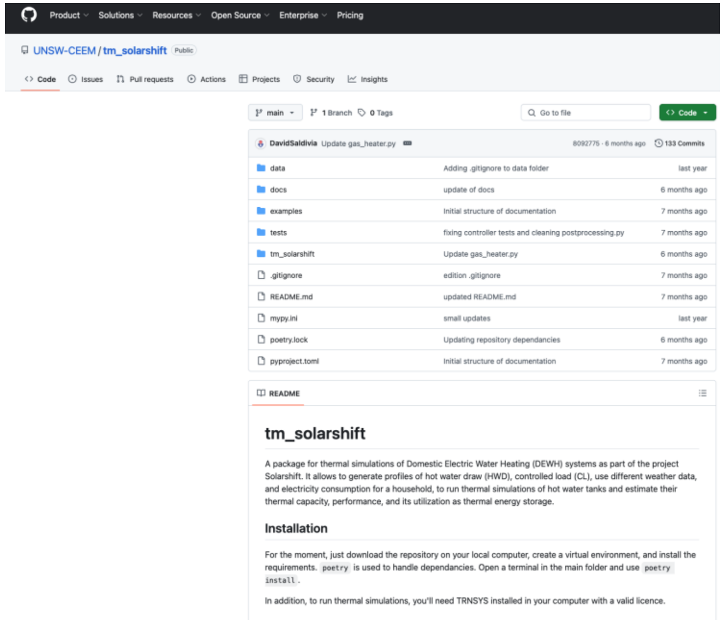
Final Knowledge Sharing Report

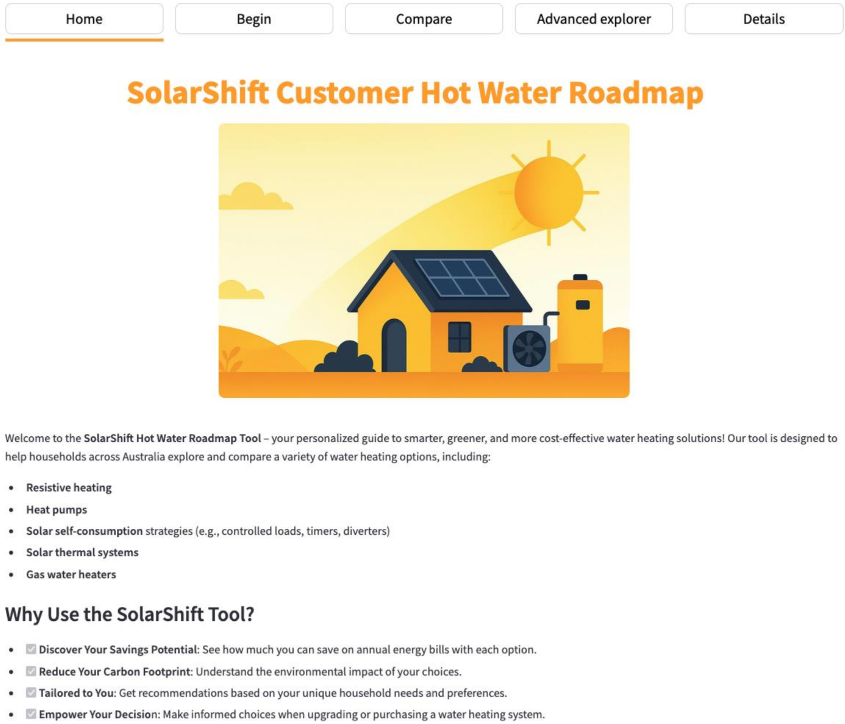
31 October 2024

PLUS·ES | agl | Collaboration on Energy and Environmental Markets | UNSW SYDNEY

[Final Report]

https://github.com/UNSW-CEEM/solar-shift





Collaboration on Energy and Environmental Markets

- 2 journal articles under review

5) Future research directions

- Improvement of Customer Hot Water Road Map tool
- Expansion and roll–out of electric water heating control onto other states and DNSP regions
- Heat pump control by smart meters
  - Collaboration with heat pump manufacturers
  - Collaboration with smart meter vendors
  - Refinement of control strategies (retailers & aggregators)
- Thermal performance and losses of hot water tanks
  - Real-world site measurements: flow meter, thermocouples (T_{in}, T_{out}, T_{tank})
  - Different climates, number of people and water usage patterns
  - Resistive and heat-pump systems
  - Cost-benefit analysis of improving water tank thermal insulation
- Input into relevant Australian Standards to update minimum energy performance standards to reflect the current status of the energy market (AS/NZS 4692.1:2005, AS/NZS 4692.2:2005, AS/NZS 4234:2021, AS/NZS 3500.4:2018)

Thank you

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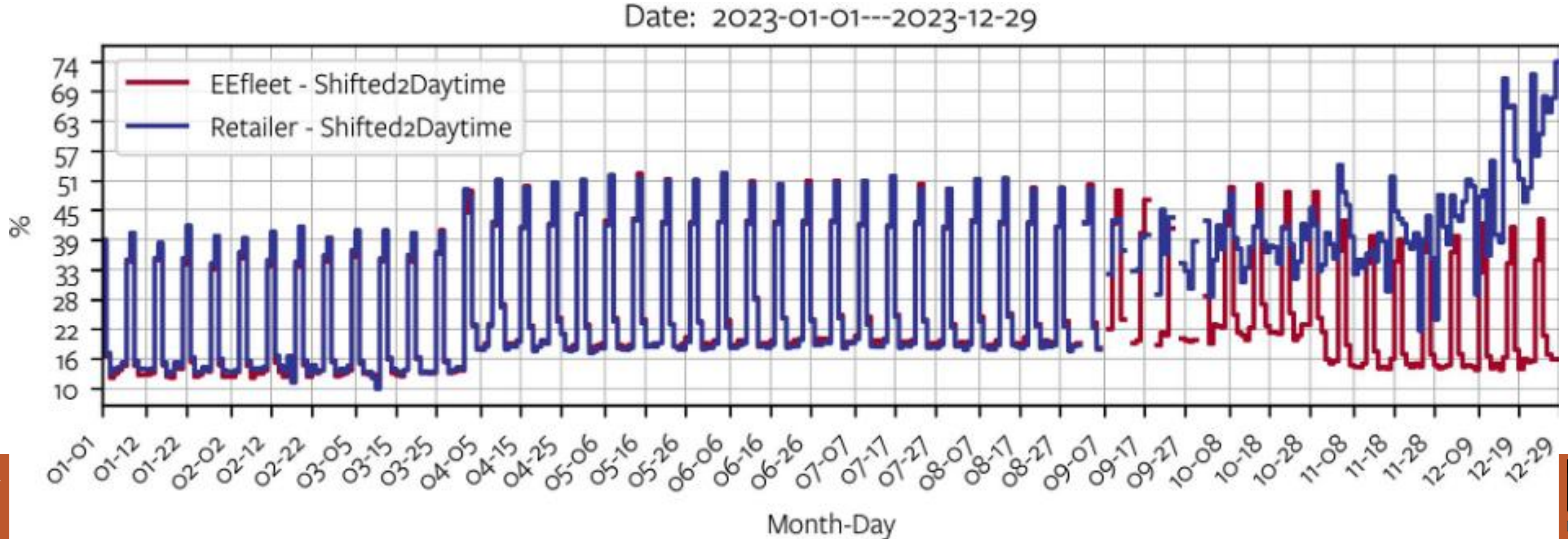
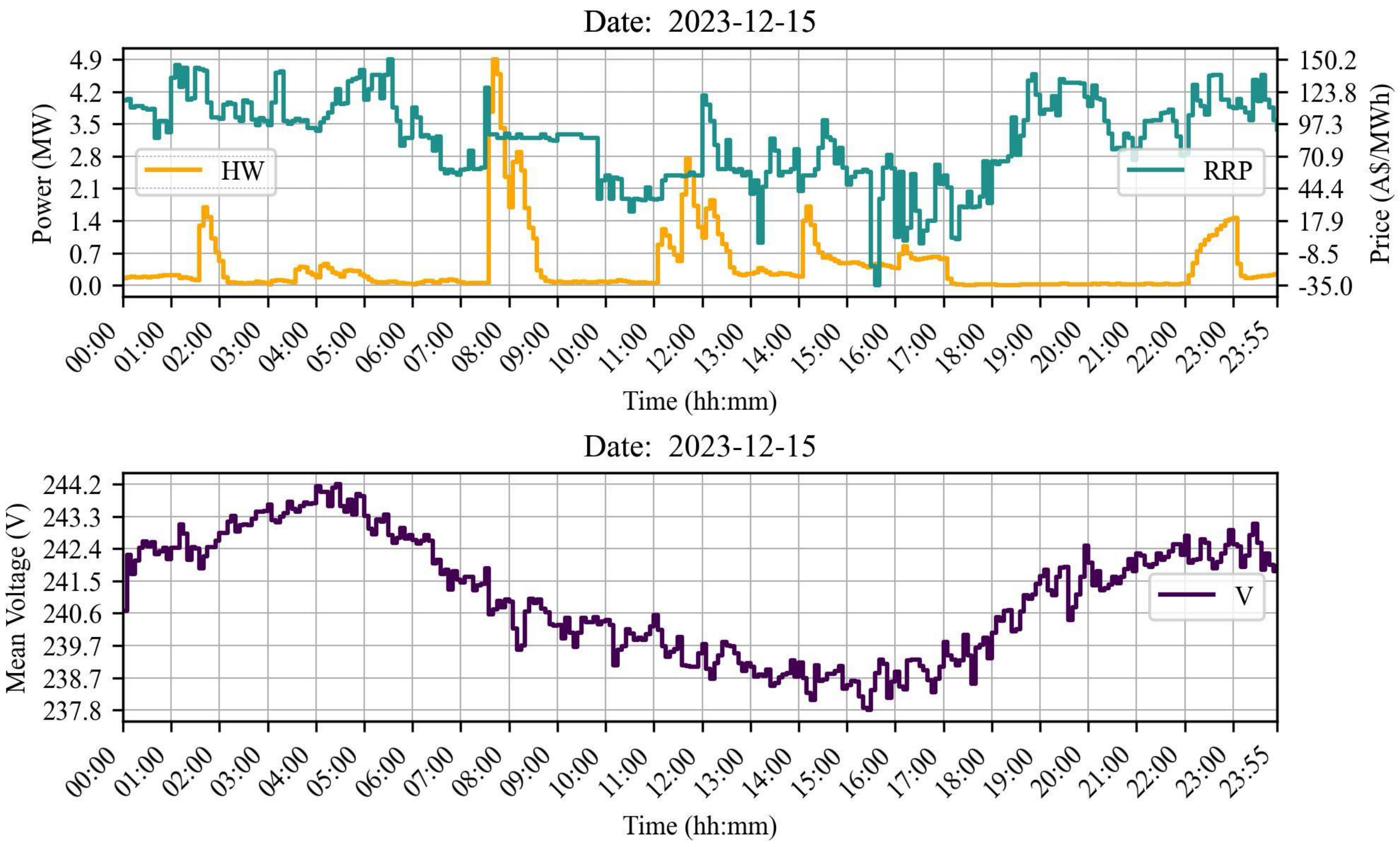
SolarShift: Off-peak plus trial by Endeavour Energy

- ~9300 households within Endeavour Energy network, mostly in Albion Park.
- One of the retailers has 37% of the fleet (‘Retailer’)
- On average 28% of water heating was shifted to daytime periods (mostly with default CL2)
- This percentage significantly increased towards the end of the studied period as the Retailer started shifting more than 70% of daily water heating to solar-soak periods
- Wholesale arbitrage benefit is estimated to be $27/household (mostly with default CL2)
- Currently households don’t benefit!
- 1 Mt-CO2 emission reduction in NSW compared to nighttime heating (8% reduction of emissions associated with water heating)



Example daily operation for the fleet against RRP



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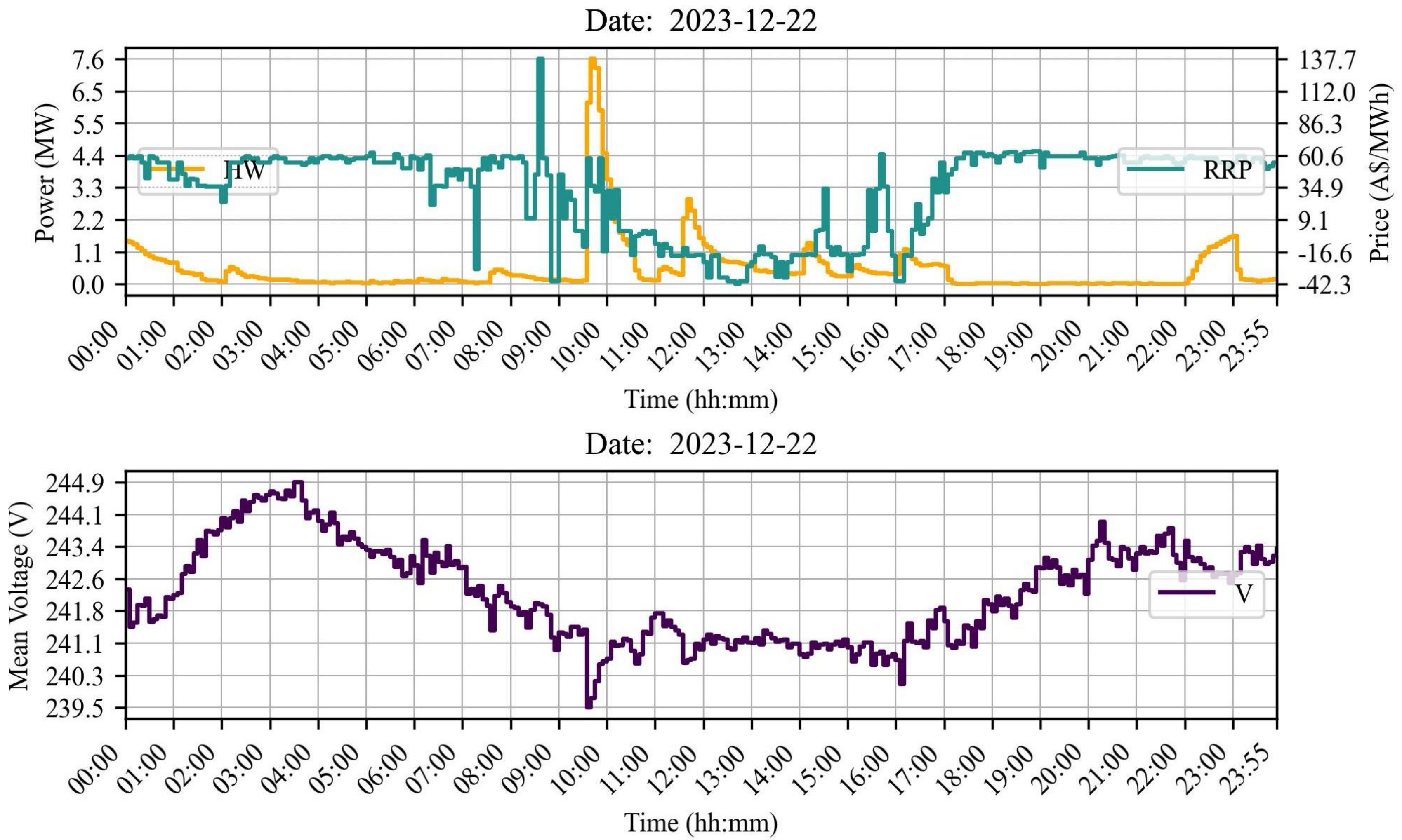

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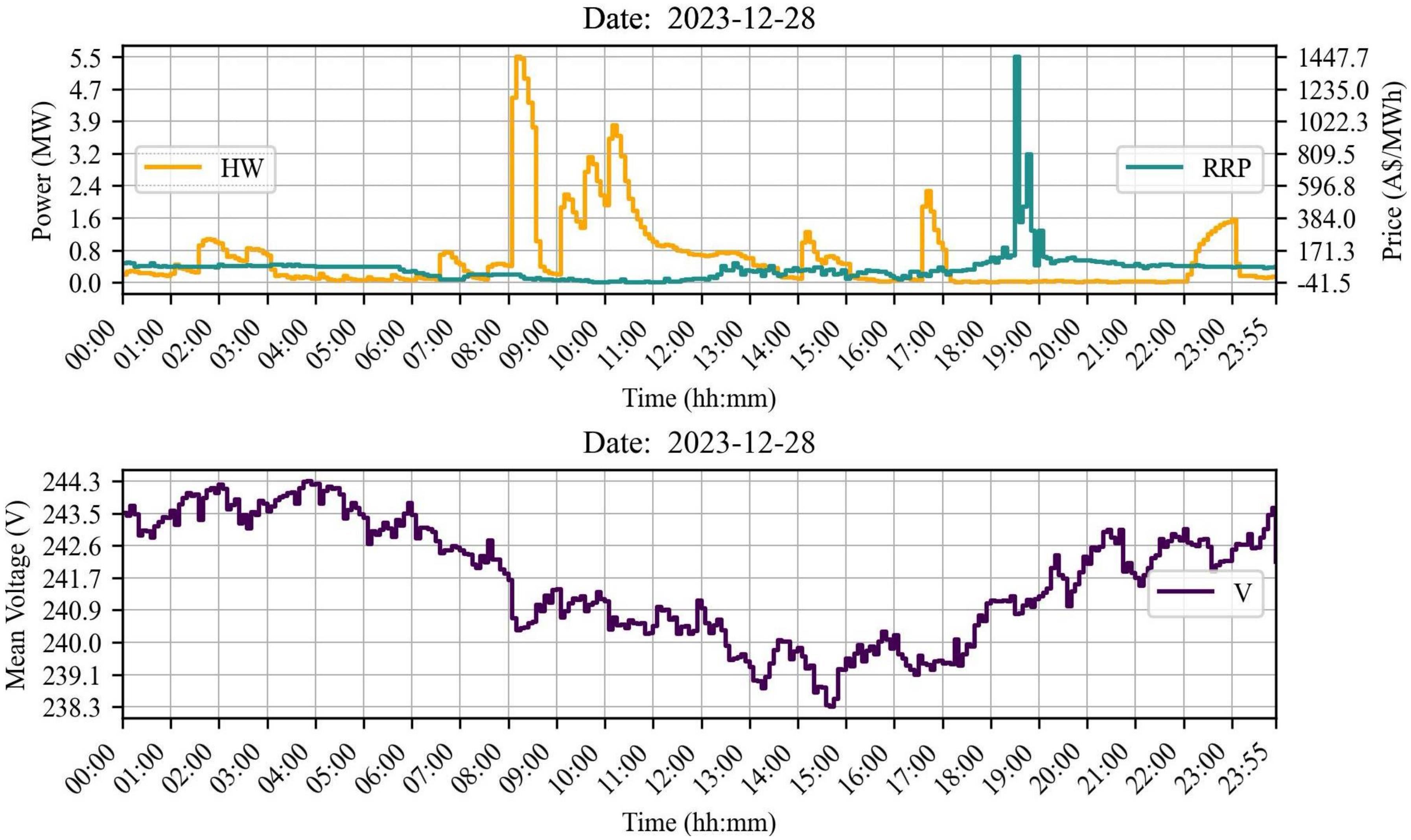
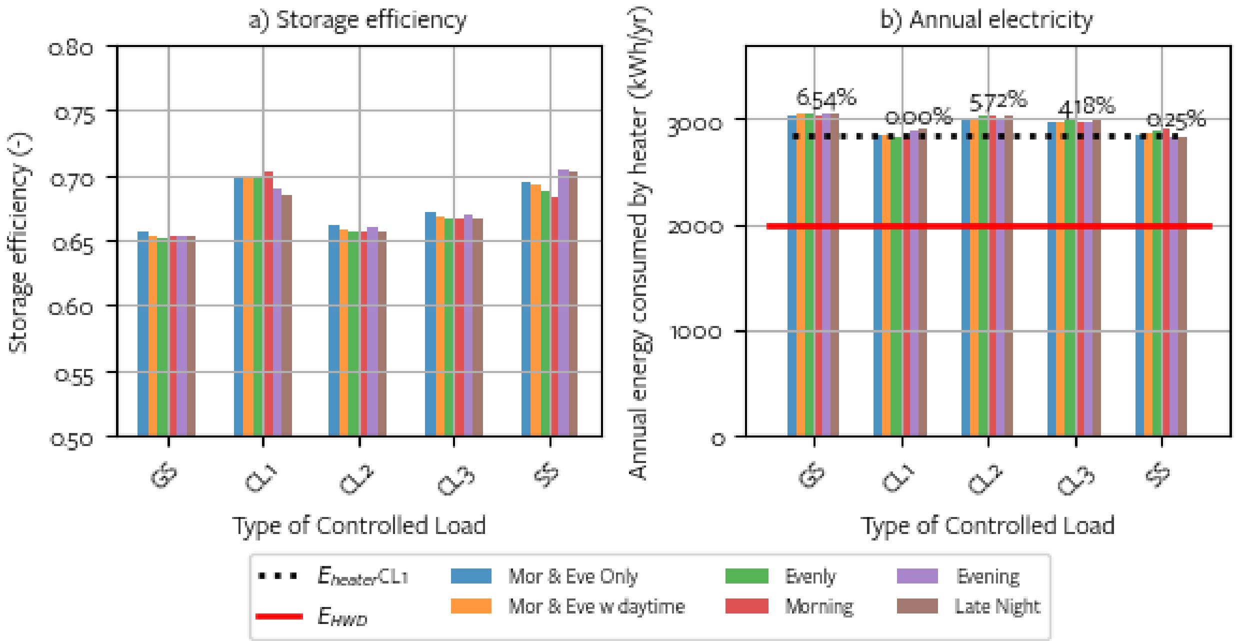


Key take-aways

- The retailer partners have found the trials to be a great success, and have plans to expand it over the other regions of NEM. Future of controlled load & hot water flex demand seems to lie with retailer/aggregator & smart meter control.
- Every DNSP has a different view on controlled load (i.e. SA, NSW vs. Qld, Vic) and there is no clear pathway to rollout capability. Current regulatory reset process is challenging for pace and scale.
  - Recommendation: National framework and reform for load control access.
- The customer journey has been smooth and relatively positive for SA Flex Demand trial as shown by customer surveys:
  - 0.1% opt-out out rate, 86% were neutral or pleased about the trial.
  - Very small number of instances of running out of hot water, having a heating period before the morning use, especially during colder months is important.
- Network tariffs offer cheaper daytime rates (some DNSPs don't charge during peak solar generation periods). Retailers should create new tariff design with cheaper day-time rates (or $0, considering solar curtailment). We have seen only a couple of examples so far with limited value for households…
- Thermal losses are significant, how can we minimize them to make electric water heating technologies even more efficient and attractive for consumers. Contribution to pathways towards electrification!

Results: Resistive heater



- CL1 and solar soak (SS) are the two schedules with better storage efficiency, with an average of 70%. GS and CL2 are the worst performing strategies.
- Control strategy has higher influence than HWDP.
- Switching from CL1 to CL3 (adding solar windows) increase energy consumption by 4%.

Detailed results for SS and HWDP=1. SOC in red.