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Hot water pathways for social housing

Evaluating electric domestic hot water system performance in social housing to inform guidelines and specifications

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Project overview

- Nine-month project (nominally) funded by RACE for 2030
- ~$180,000 budget
- One research partner: UTS (plus UNSW on IRG)
- Four main industry partners:
  - LAHC (now Homes NSW)
  - AHO (now Homes NSW)
  - Ausgrid
  - Essential Energy
- Other IRG members:
  - RACE for 2030
  - EEC, Solar Victoria, NSW DCCEEW
  - UNSW

Project objectives and outputs

- **Project objectives**—support a rapid shift towards more efficient, flexible, sustainable and cost-effective domestic hot water through:
  - Improving market clarity, and
  - Influencing provider practices
- **Project outputs**
  - Research report, that includes:
    - Market scan (current and future products)
    - Design choice primer (guidance on design decisions)
    - Guidelines and product specifications (to guide selection)
    - Appendix (details, comparative data etc.)
  - Heat pump energy usage data

Key research questions

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- What heat pump how water systems are currently available? **Market scan**
- How mature is the current market, and what alternative water heating products are currently or likely to be available in the foreseeable future?
- What are the key specifications of heat pump domestic water heaters that are likely to affect their performance in terms of cost, user experience, environmental impact and network impact, and how do currently available products differ across these key specifications?

Interviews

- Which key variables (e.g. household size, climate zone, existing solar) and decision points (e.g. product selection, timer settings) need to be considered to deliver best practice solutions?
- What are the consequences of the various decision options in terms of cost, user experience, environmental impact and network impact? e.g. What are the consequences of operating a heat pump water heater as a controlled/flexible load?

Pilot analysis

What HPHWSs are currently available?

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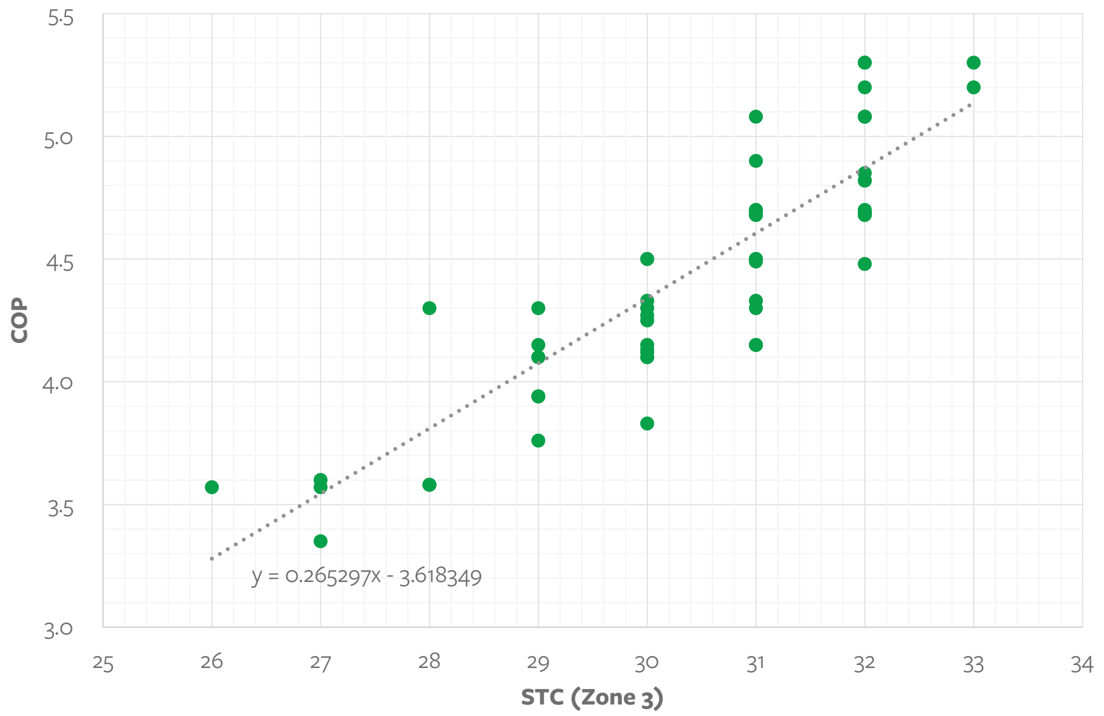
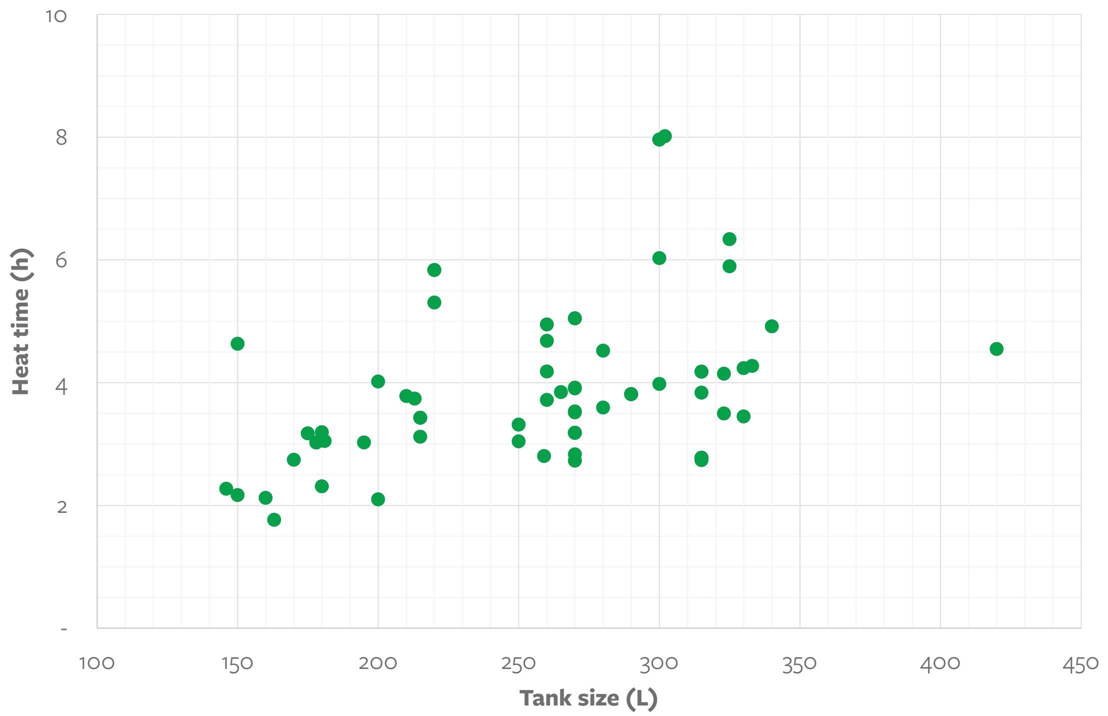
- Market scan complete, covering **71** domestic products across **20** manufacturers/suppliers
- Basic specifications
  - **Type** (integrated or split)
  - **Refrigerant** and its GWP (14 × R744, 29 × R290, 1 × R513A, 27 × R134A)
  - **Tank size**, materials and sacrificial anode type
- Performance indicators
  - Ambient **temperature** operating range
  - **STCs** (across all five zones), and NSW ESS/VEEC compatibility
  - **COP**, input power (plus derived parameters of heating capacity and heat time)
  - **Boost power**
  - **Noise**
- Reliability indicators
  - **Warranties**
  - *Product Review* scores
- Controls
  - Built-in **timer controls**
  - Optional **Wi-Fi controls**
  - **Controlled load** compatibility
- **Price** (where available)

Insights from market scan



There is a reasonable correlation between STCs and COP figures quoted by suppliers at standard test conditions



Compressor sizing is highly variable, resulting in a wide range of heat times

Insights from market scan

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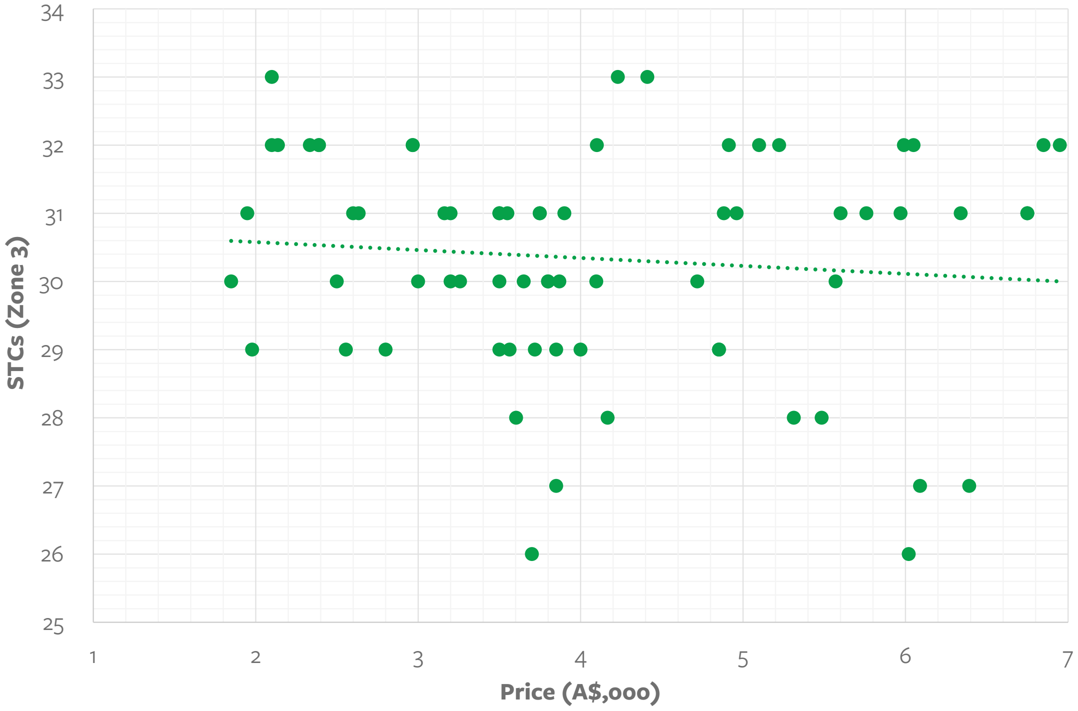
Energy performance has been increasing at ~1%/year ...

... but there is no correlation between energy performance and price



Insights from market scan

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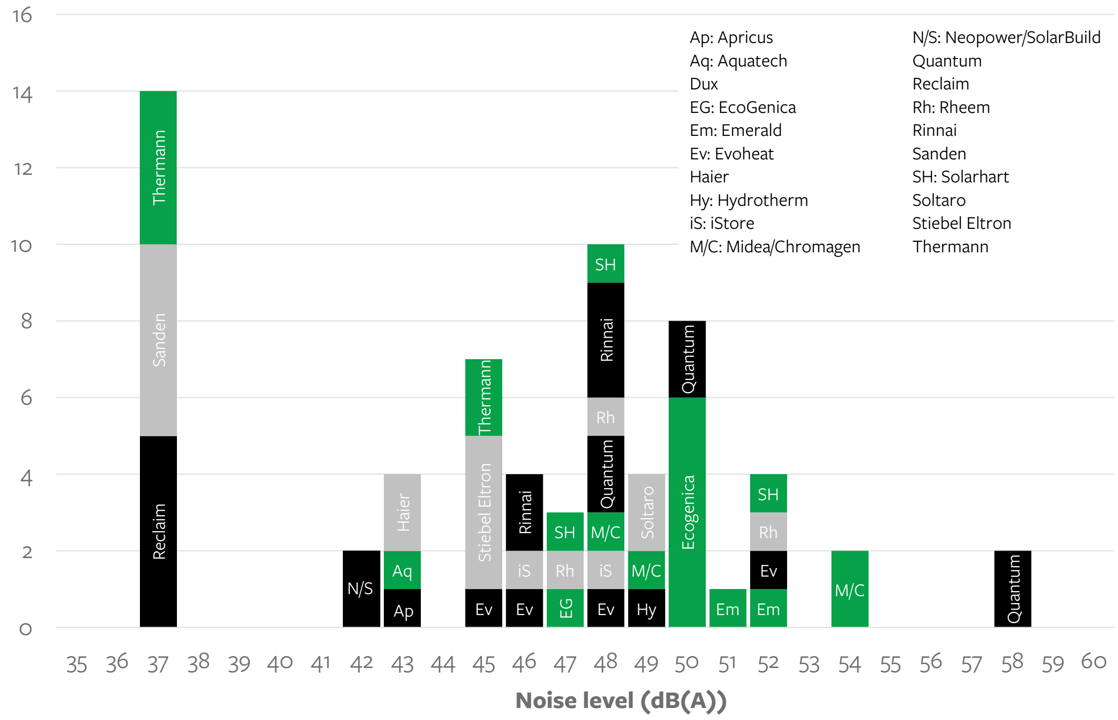
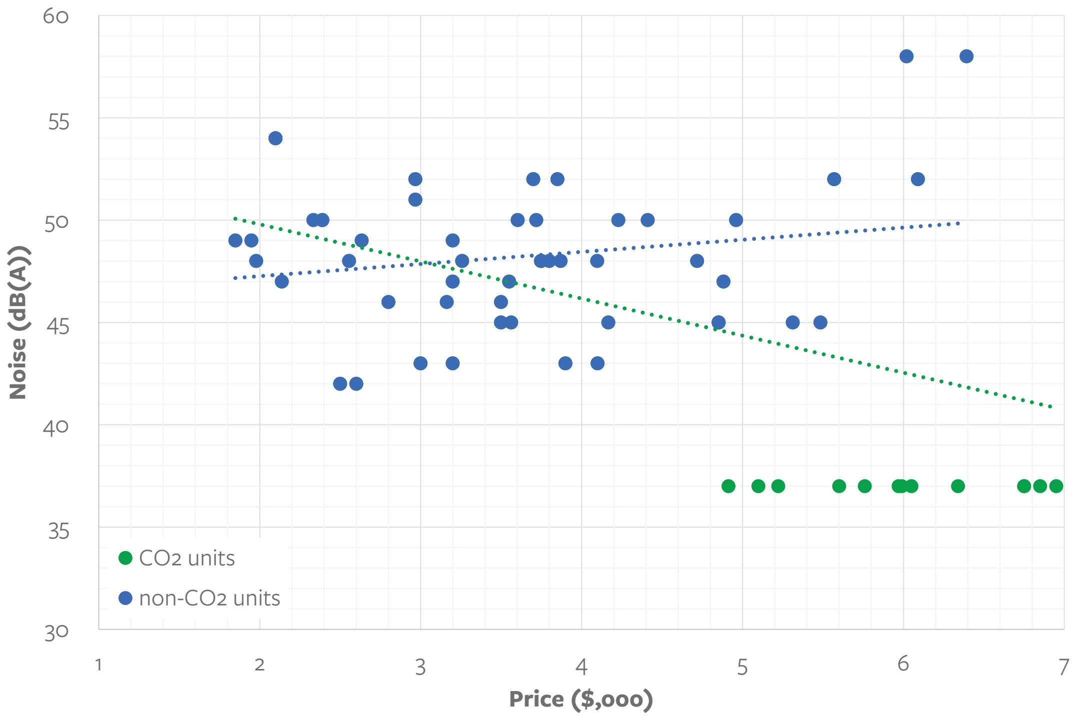


There are large differences in noise levels ...



... and more money can buy you a quieter unit if you opt for CO2

Insights from market scan

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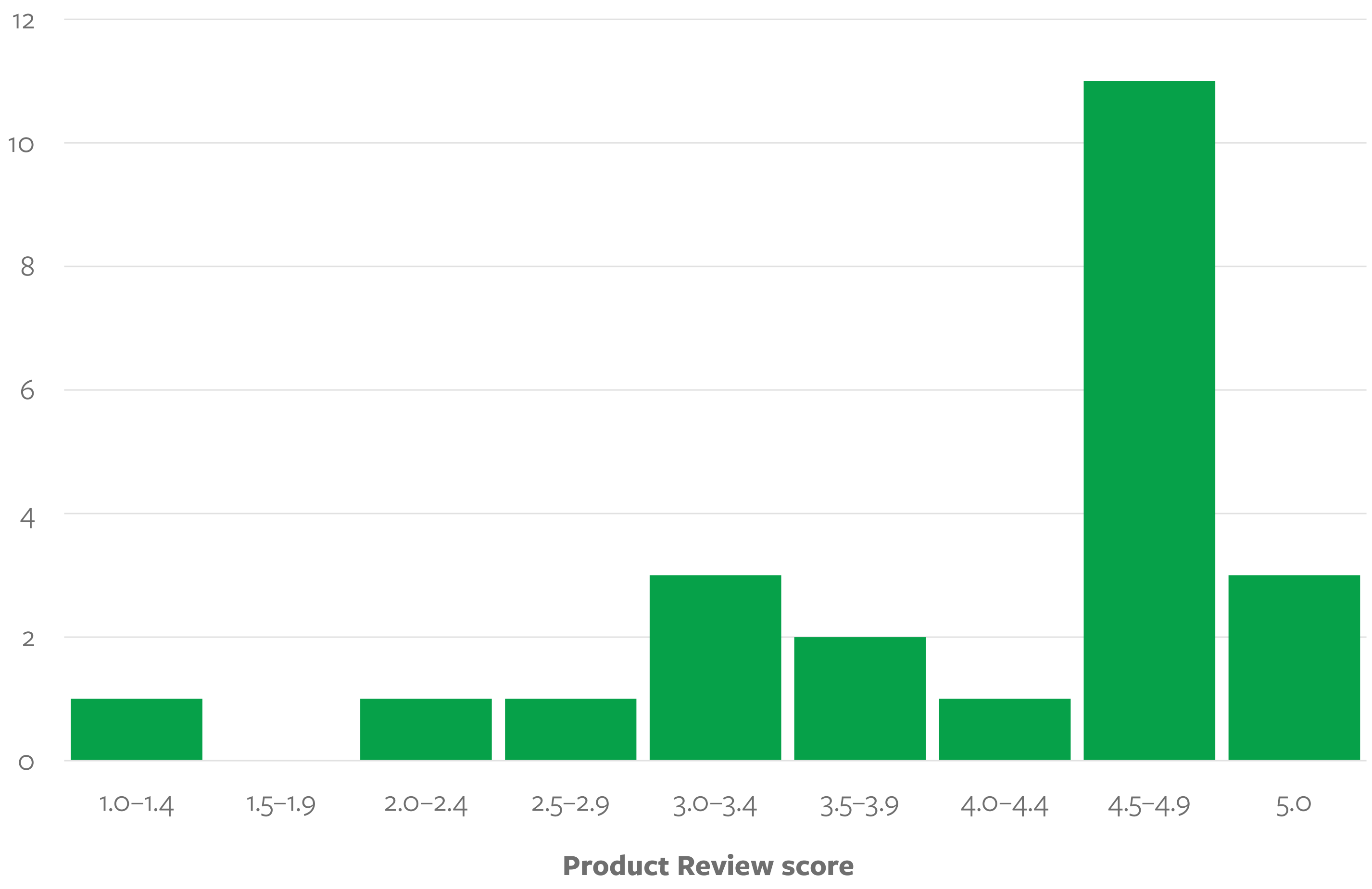
There are large differences in Product Review scores.

Brands with average scores over 4.5 and at least 50 reviews include:

- Haier (5.0 from 78 reviews)
- iStore (4.9/114)
- Evoheat (4.8/909)
- Reclaim Energy (4.8/84)
- Aquatech (4.7/1371)
- Hydrotherm (4.7/315), and
- Emerald Energy (4.6/135)



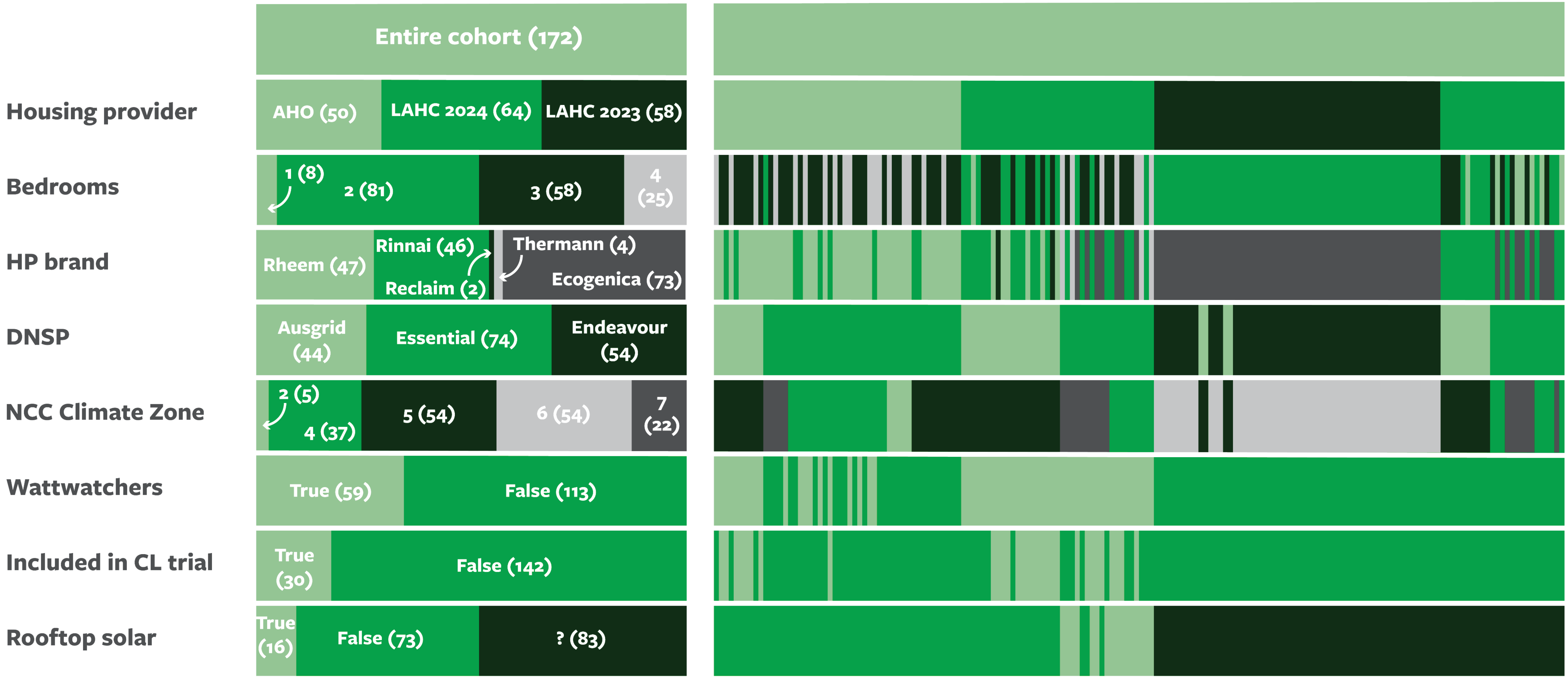
Common interview themes and market trends

Current market trends	Refrigerants	• Move from R134A to R290 (high to low GWP)
	Coefficient of Performance	• COPs have increased over time (about 1% per year based on STCs)
	Split vs integrated systems	• Shift from split to more integrated systems (cheaper installation, more 'like-for-like' replacement)
	Fast evolving technology	• Timers now almost ubiquitous (but not very sophisticated) • Optional Wi-Fi controls now common (low-cost technology), linked to apps • Eco-mode options available (by switching off boost element and increasing dead band) • Demand for smarter management and solar soaking • Simplified installations (e.g. quick connect systems)
	Mature, two-tier market	• High tier (Sanden, Reclaim, Thermann): CO2 refrigerant, SS tanks, 10–15-year warranties, quieter • Low/middle tier (everything else): R290/R134A refrigerants, GL tanks, 5–7-year warranties, noisier
Supply chains	Supply chain and market	• Most compressors are manufactured in China • "Some retailers only in the market for rebates, creating an artificial market" • "Local manufacturing cannot beat the price of cheap overseas products"
	Product quality	• Relatively mature market (increasing product numbers, diversity, performance and warranties) • No tangible evidence for low quality products 'flooding the market' (though many anecdotes)

Common interview themes and market trends

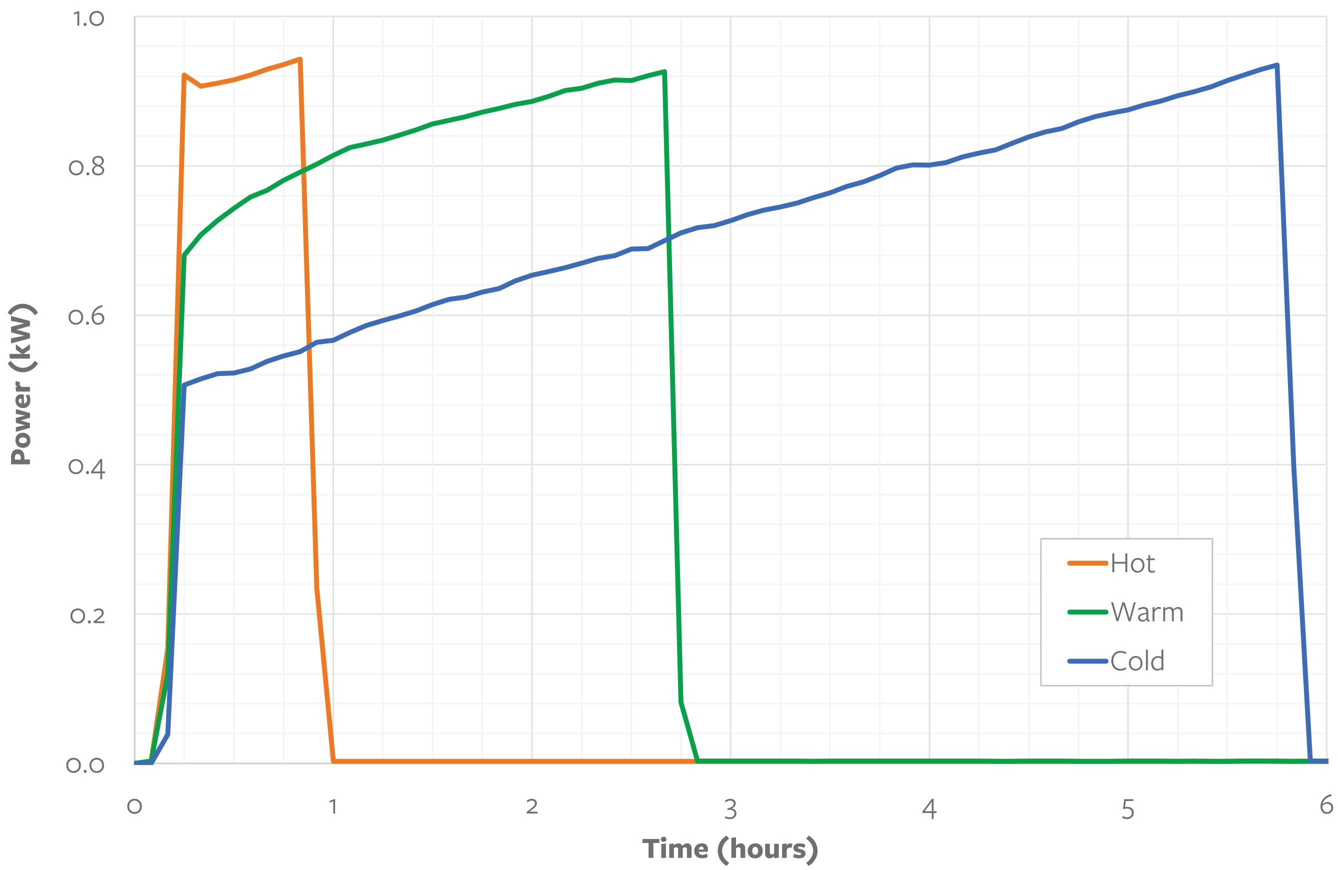
Market transition issues	Installation issues	• Evidence for poor quality installation practices among some operators (though improving) • Split system installation can be challenging, as skilled plumbers needed
	Barriers for load flexibility and need for increase in consumer knowledge	• Many products in the market have controlled load as an option now • Should be convenient for users • Separate controls for requirements and should be able to turn back to the most efficient mode eventually
Future market opportunities	Solutions for apartments	• Smaller systems, wall mountable • Splits systems with a tank that can fit in a cupboard • Models with elements at the top • "Industry is ready if government is ready to support innovation"
	Product improvements	• Further shift towards propane and other low GWP refrigerants (phase out of R134A) • Non-flammable refrigerants (though less of a problem in Australia with outdoor installations) • Further efficiency improvements (e.g. reduced default storage temperatures, better tank insulation) • Quieter units (bigger, slower fans) • Designs that allow easier maintenance (e.g. easy anode replacement)
	Better load matching	• Variable speed compressors (c.f. inverter air conditioners), enabling better solar soaking • Smarter control systems (adaptive, machine learning, connected to solar inverter etc.)

Pilot details



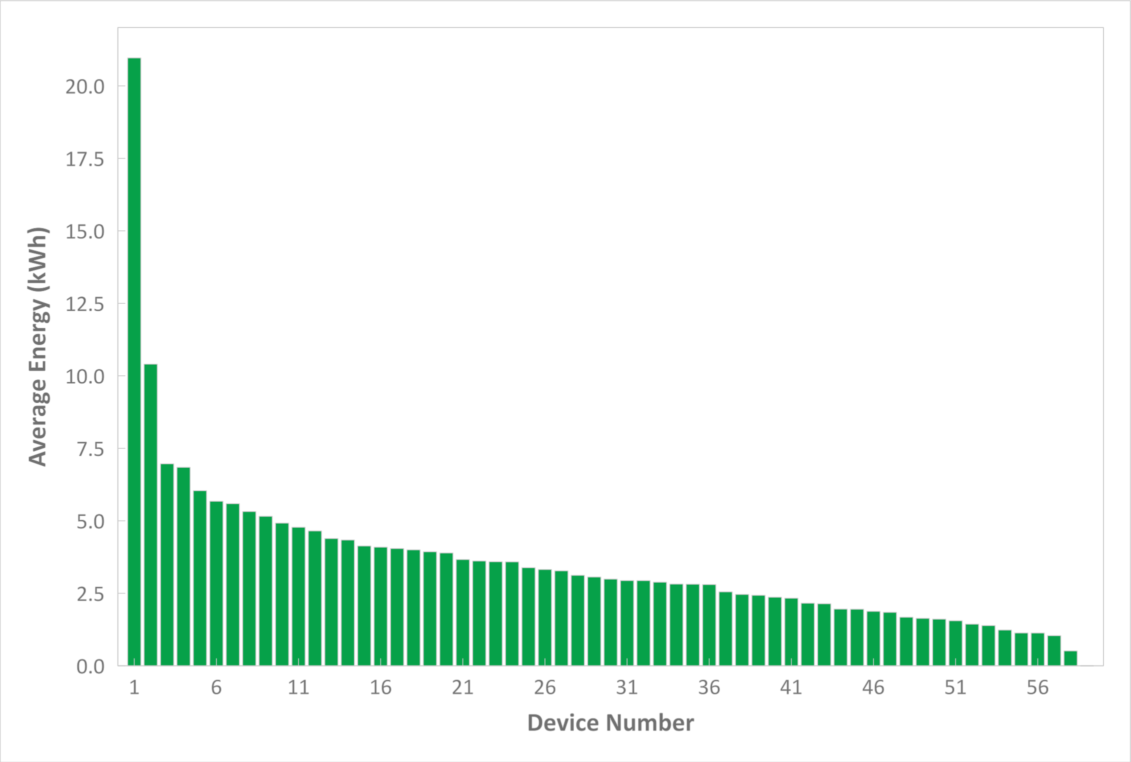
Heat pump operating curves

- 59 × HPHWSs fitted with Wattwatchers monitoring devices, with 5-min resolution
- Devices enable detailed monitoring and analysis of cohort

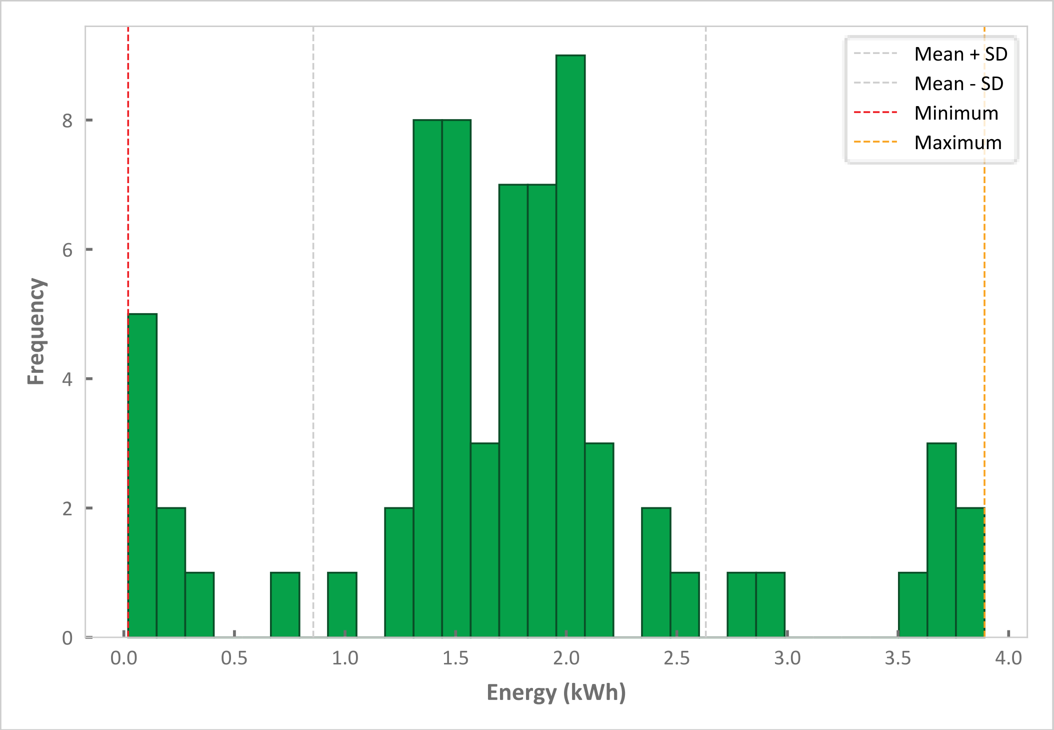


Energy use

- Preliminary cohort analysis possible based on 6–44 days of data (to be updated when more data available)



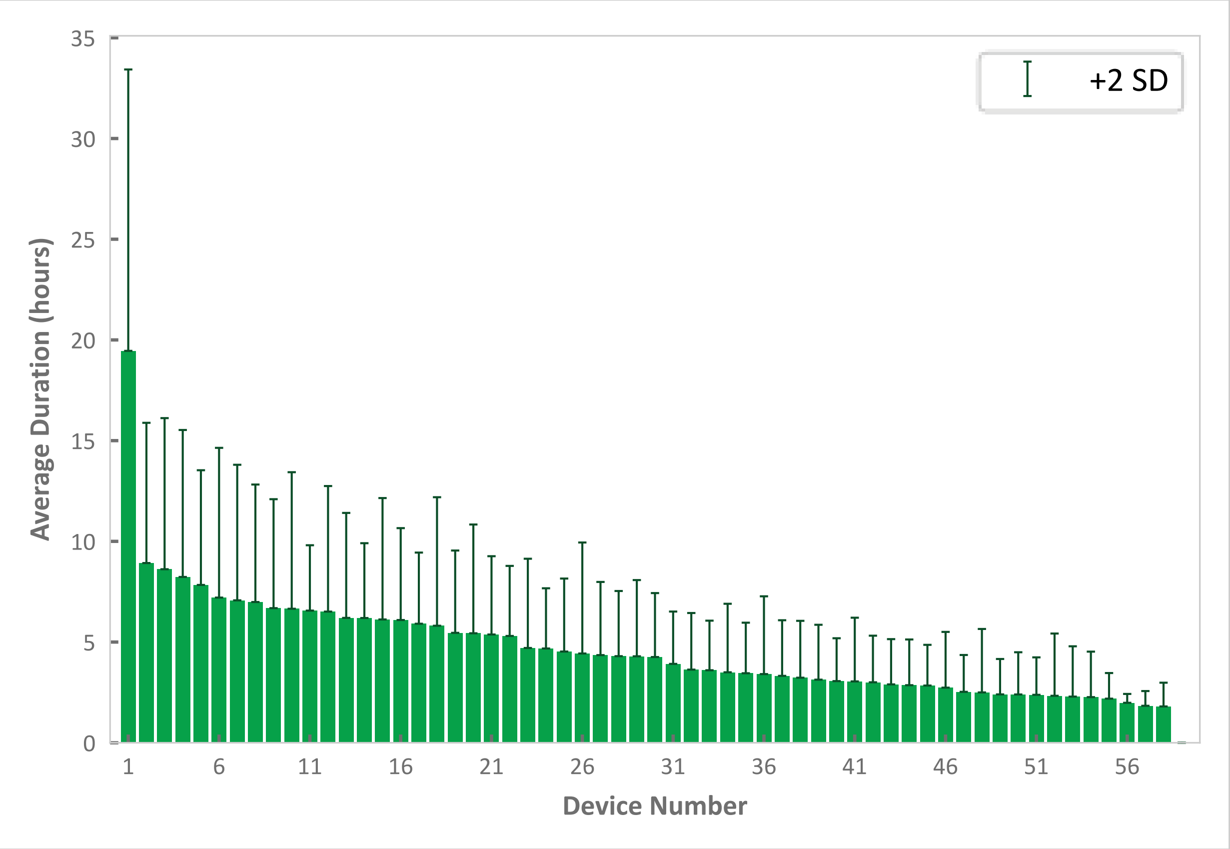
Average daily energy use of HPHWS across Wattwatchers cohort



Daily energy histogram device DD13710149470

Duration of operation

- Average daily hours of operation = 4.7 (across cohort), and <9 for almost all units (winter months)
- However, large daily variance means CL1 (6 hours) not suitable for large proportion of cohort



Element	Value	Units
Average daily HPHWS energy consumption	3.6	kWh
Average daily operation duration of HPHWS	4.7	hours
Standard deviation of operation duration of HPHWS	41.3	%
Smallest average duration across all 58 HPHWS	1.3	hours
Largest average duration across all 58 HPHWS (excl. 1)	9.1	hours

Average daily operation duration across Wattwatchers cohort

Boost elements

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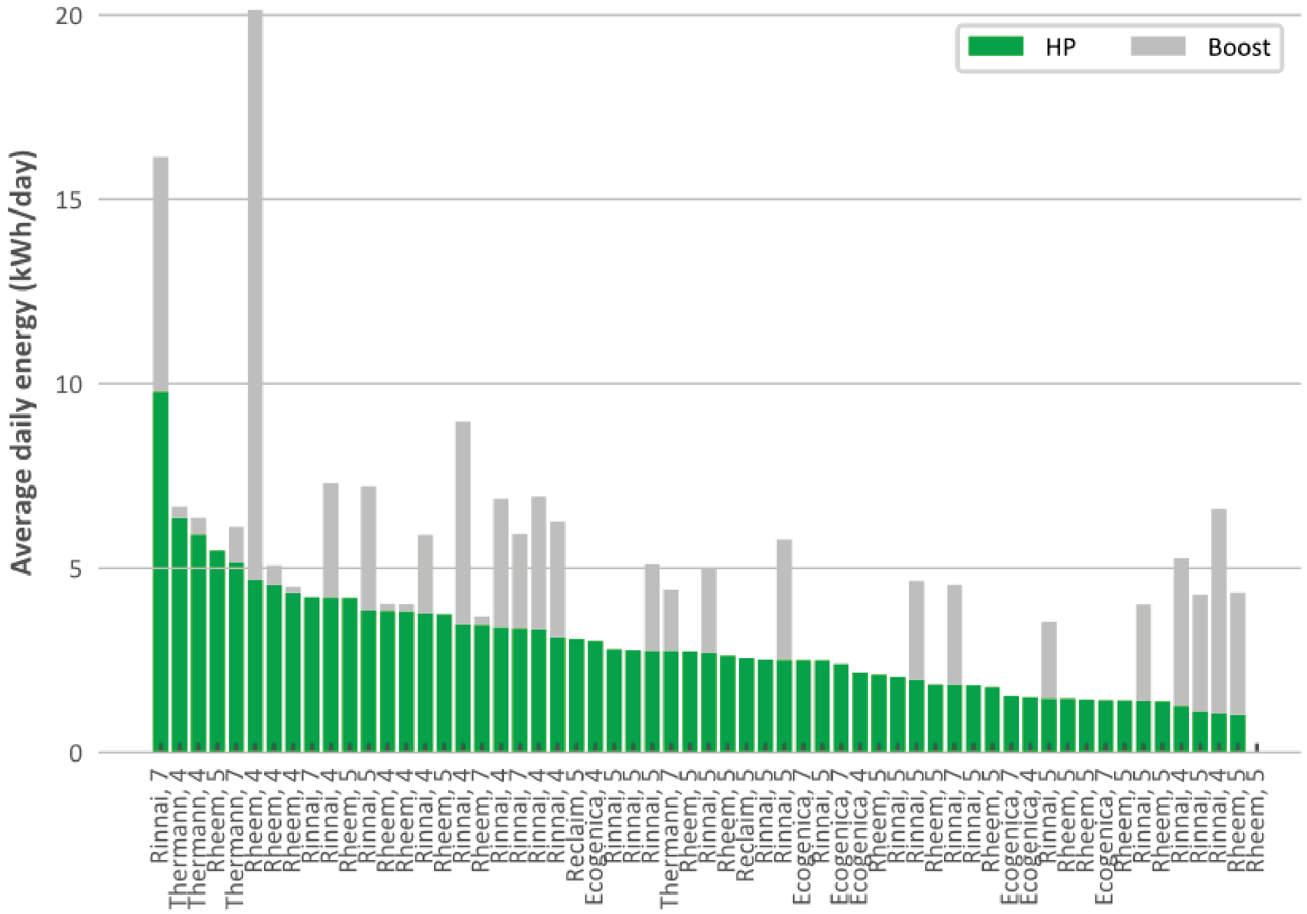
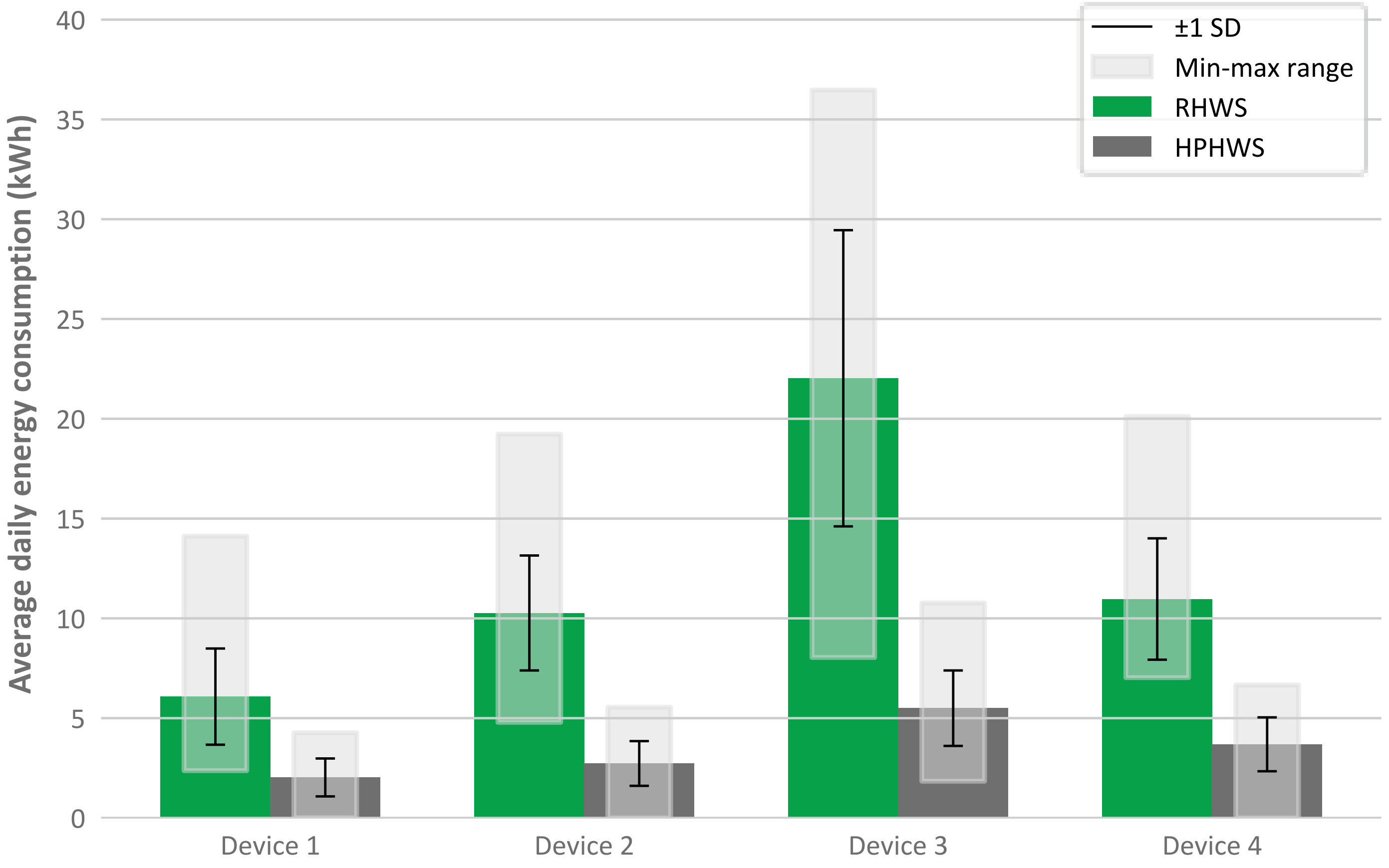
- Rheem and Rinnai units include 2.1–2.4 kW boost elements
- Whether a boost element operates depends on:
  - Program mode
  - Hot water usage
  - Climate and weather
- Decision on whether a boost element is ‘necessary’ is complex



Energy savings

- Interval meter data provided by Ausgrid allows for detailed comparison for four Maitland properties (2023 versus 2024)
- All properties upgraded from resistance water heaters to Rheem HPs
- No correction for ambient temperatures (to be included in later analysis)
- Measured energy savings for period 9 July – 8 September (2023 vs 2024) are 62–78%



Bill savings

- Bill savings estimated for period 9 July – 8 September (2023 vs 2024)
- To estimate bill savings, we assumed:
  - Resistance heater operates on Red Energy CL1 tariff (Ausgrid) of 15.86 ¢/kWh
  - Heat pump operates on Red Energy Living Energy Saver flat tariff (Ausgrid) of 29.87 ¢/kWh
- Estimated savings of ~$11–56 per month
- Future analysis to include bill saving opportunities for:
  - ToU tariffs
  - Solar self-consumption (both actual and optimised)

Device ID	Resistance hot water cost	Heat pump hot water cost	Difference	Difference
	($)	($)	($)	(%)
DDC3710149677	58.78	37.53	21.25	36.2
DD63710149492	99.34	50.56	48.78	49.1
DD53710150218	213.10	101.89	111.21	52.2
DD33710150289	106.10	68.35	37.75	35.6

Operating times

- Operating times compared for period 9 Jul – 8 Sep (2023 vs 2024)
- Average heat pump operating times are 32–89% greater than for resistance units (difference lessens as water use increases

Device ID	Resistance hot water average operating time	Heat pump hot water average operating time	Ratio
	(h/day)	(h/day)	
DDC3710149677	1.9	3.6	1.9
DD63710149492	3.2	4.7	1.5
DD53710150218	6.5	8.6	1.3
DD33710150289	3.4	5.9	1.7

Solar self-consumption

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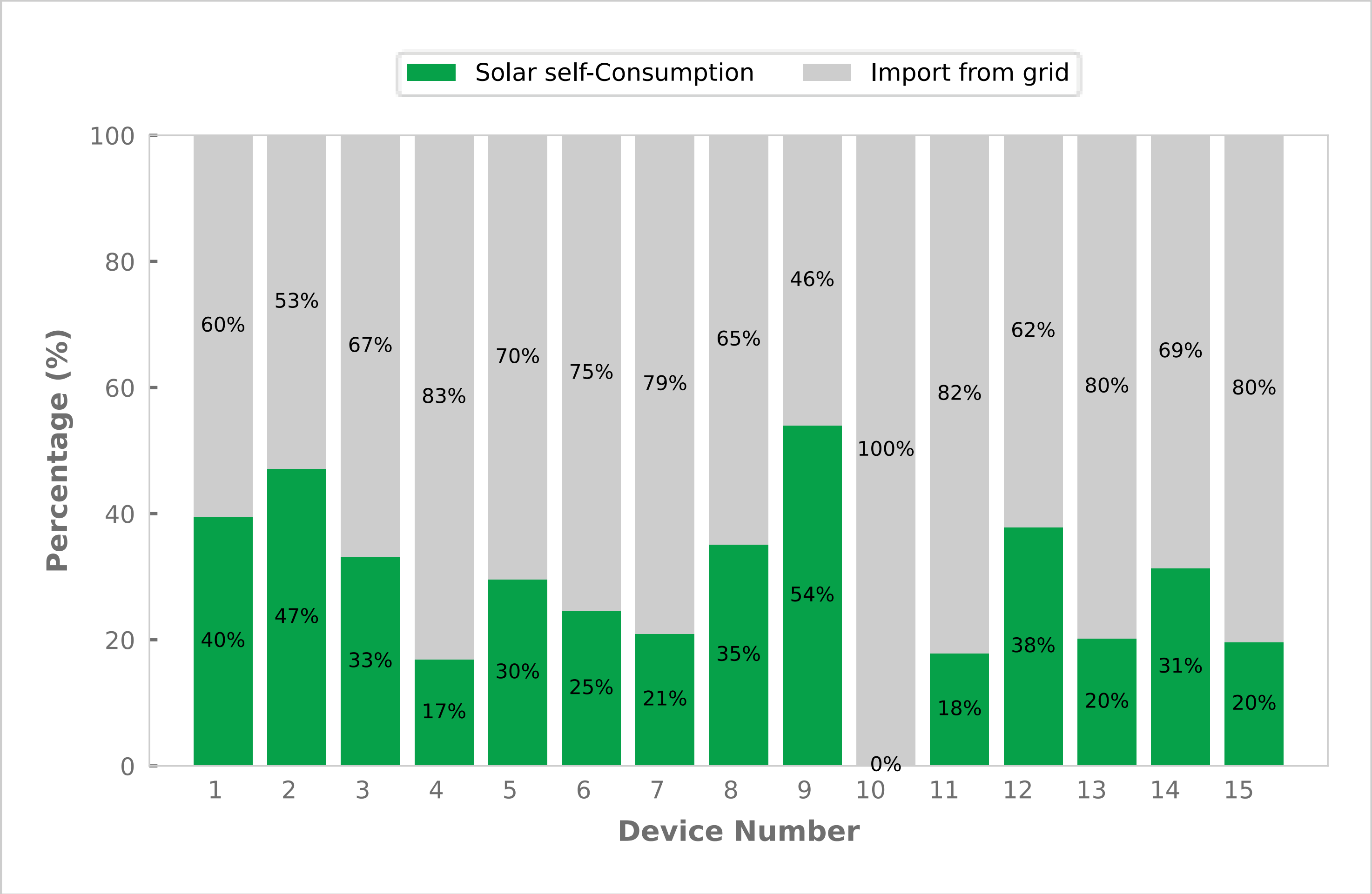

HPHWS energy usage: Percentage of solar self-consumption compared to grid imports from 9 Jul – 8 Sep 2024

Controlled load

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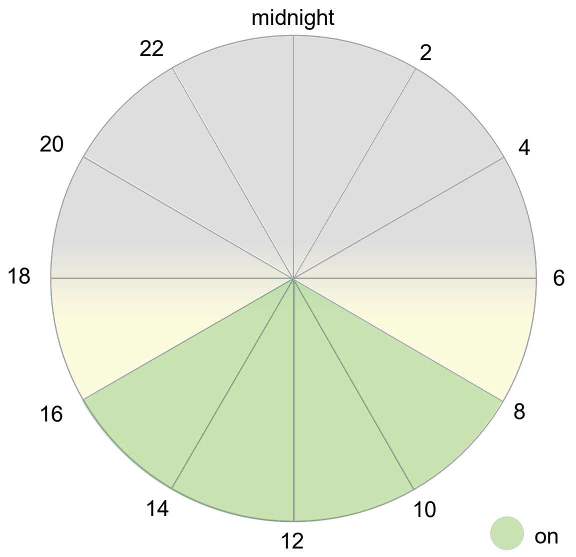
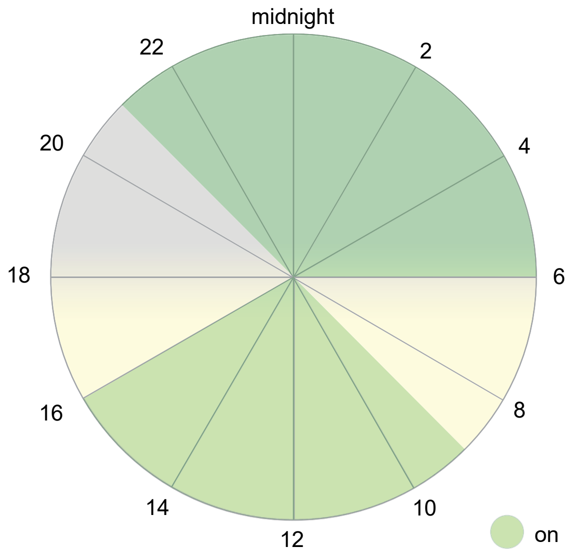
- Off peak hot water is the original Consumer Energy Resource
- Ripple control has been used since the 1950s in NSW to control off-peak hot water
- Traditional advantages of controlled load:
  - For electricity utilities: keep coal plants operating at night when demand was otherwise low
  - For electricity users: cheap electricity for heating water
- DNSP-managed controlled load is moving away from nighttime towards daytime operation, corresponding to the 'solar window'
- Heat pump hot water systems are typically being installed on continuous circuits
- Heat pump timing can be controlled in other ways (timers etc.)
- Some central questions of this project include:
  - Should heat pumps be operated as controlled loads, and under what conditions?
  - What are the costs and benefits of changing the time at which heat pumps operate?
  - What are the best ways to control timing of heat pump operation?

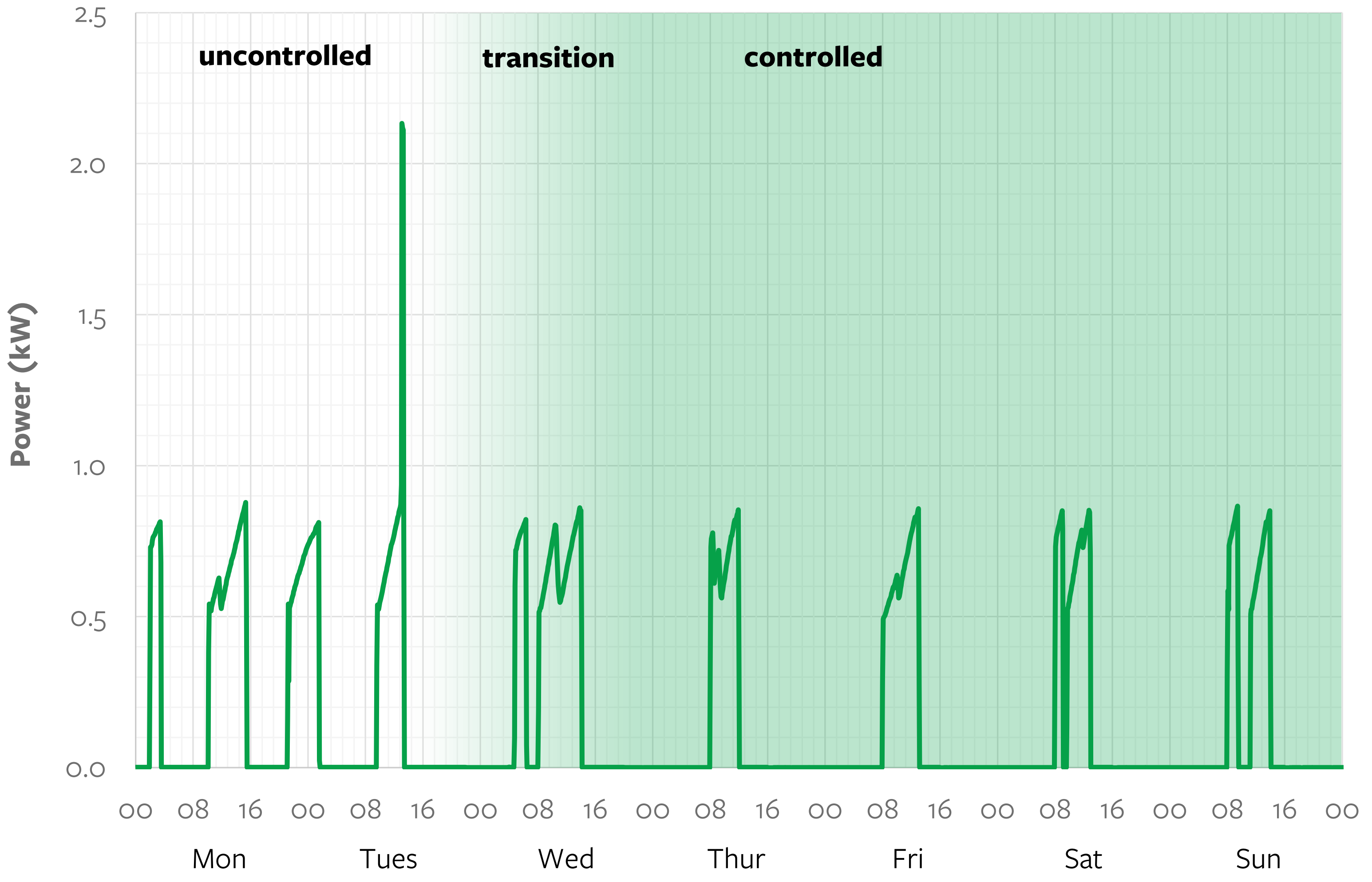
Simulated controlled load interventions

- Pilot includes two simulated controlled load interventions
- 30 (CL1) and 45 (CL2) units selected, based on criteria:
  - {model suitable for controlled load operation} AND
  - {consent provided by tenant} AND
  - {Wattwatchers online, no problems detected} AND
  - CL1 trial: {(maximum daily operating hours < 10) OR
    (average daily operating hours + 2SD <10)}
  - CL2 trial: {(maximum daily operating hours < 16) OR
    (average daily operating hours + 2SD <16)}
- Interventions
  - CL1 trial: 0800–1600 AEST (8-hours)
    19/9/24–16/10/24 (28 days)
  - CL2 trial : 0900–1600 and 2100–0600 AEST (16-hours)
    23/10/24–19/11/24 (28 days)





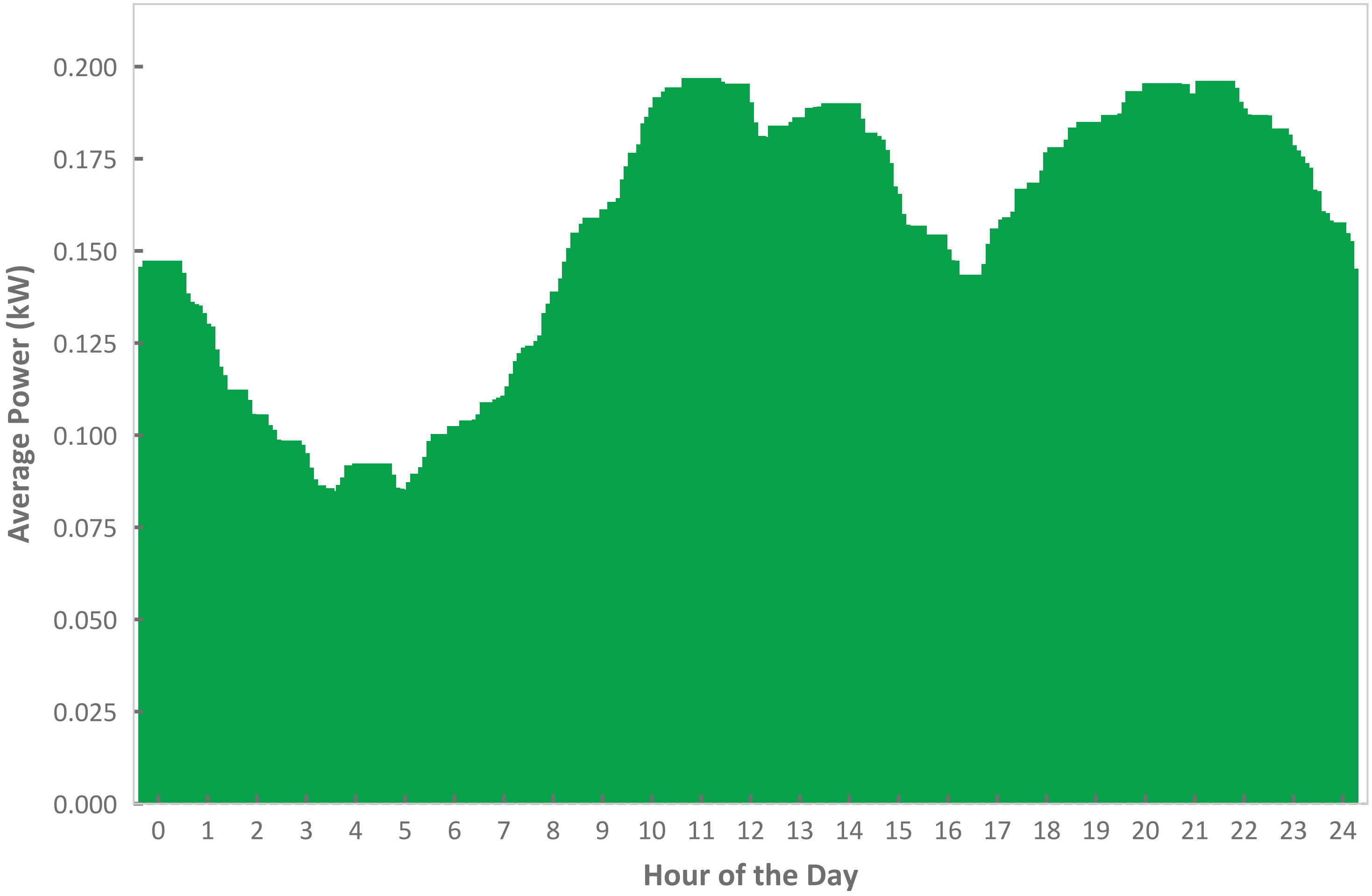
Early data from controlled load intervention



Advantages of daytime operation:

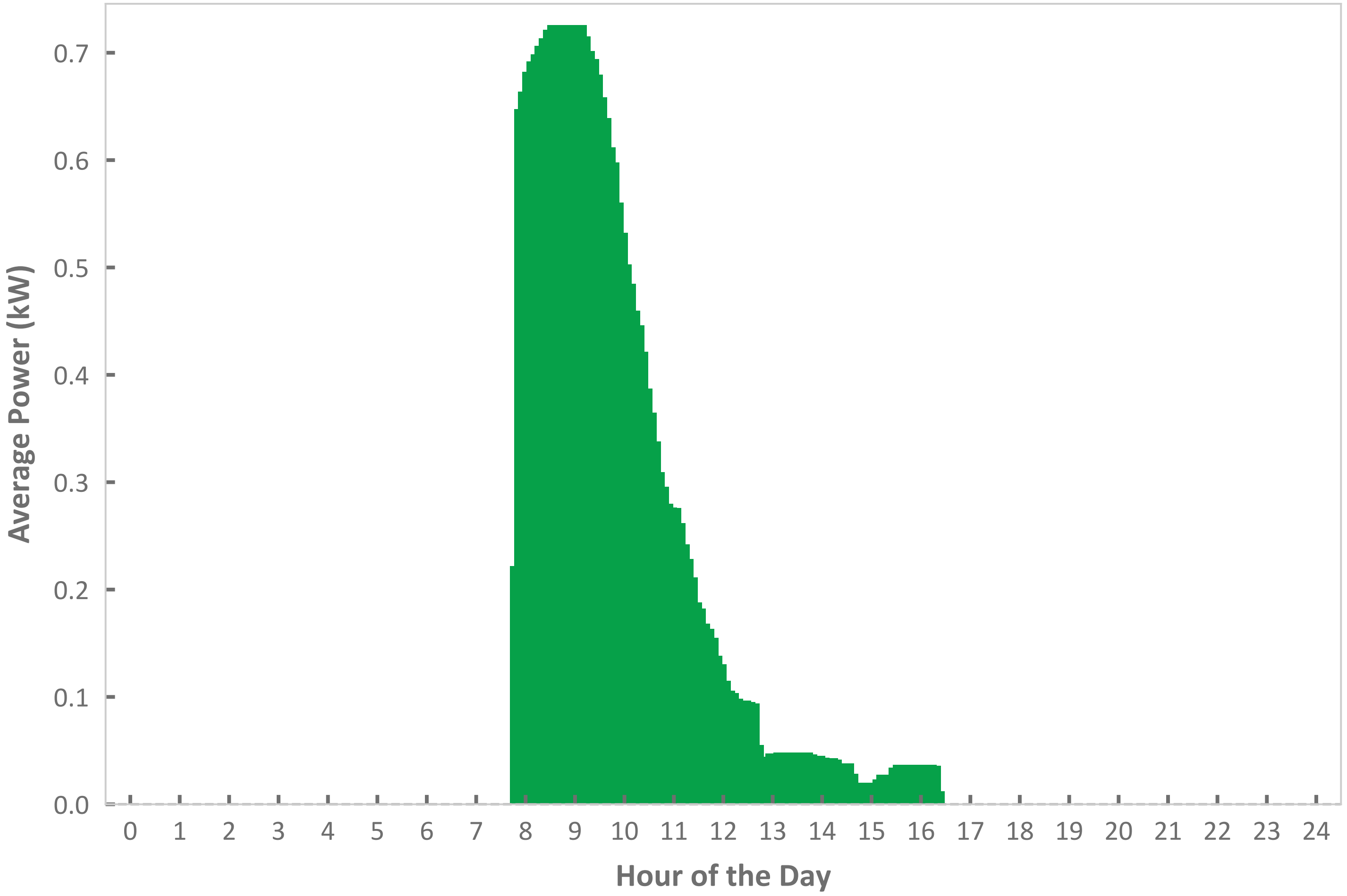
- Higher efficiency (warmer air)
- Increases solar self-consumption (where available)
- Lower operating costs for ToU tariffs (solar soak)
- Reduces noise concerns

Time of operation (uncontrolled)



Average daily operating times across Wattwatchers cohort, 9 Jul – 18 Sep 2024

Time of operation (controlled)



Of the 30 devices in the intervention trial, 11 were affected by Wattwatchers devices being offline at time of switching.

Shown is the average daily operating times for the remaining 19 devices in the intervention trial, 19 Sep – 16 Oct 2024.

Heat pumps on controlled load

- Many manufacturers recommend against operating on non-continuous (controlled load) circuits
- Potential problems with 'traditional' (e.g. ripple-control) controlled load include:
  - Regular 'uncontrolled' switching of compressors can compromise product lifetimes (esp. CO_2)
  - Increased risk of water freezing in pipes, especially if switched off overnight
  - Introduced risk of water not regularly getting to 60°C to kill *Legionella*
  - Increased risk of hot water deficits (smaller tanks, slower heating cycles)
  - Overnight controlled load creates potential noise issues
  - Metering arrangements usually mean choosing controlled load OR solar self-consumption, not both
- Alternatives to ripple control include:
  - Uncontrolled operation (often the default state)
  - User controls: internal timers, Wi-Fi controllers, inverter signals, HEMS
  - Network controls: external timers, smart meters

What control is needed to maximise benefits?

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- Who benefits? There is no perfect option that benefits everyone (yet)
- Housing providers need foolproof operation, not complex control systems

Control option		Resident benefits: Hot water availability	Resident benefits: Bill savings from Tariffs	Resident benefits: Bill savings from Solar	Housing provider benefits: Minimised risks/costs Service calls	Housing provider benefits: Minimised risks/costs Unit reliability	Network benefits: Flexible demand Passive	Network benefits: Flexible demand Active
Uncontrolled		✔ (green)	✘ (red)	✘ (red)	✔ (green)	✔ (green)	✘ (red)	✘ (red)
User controls	Internal timer	✔ (orange)	✔ (green)	✔ (orange)	✔ (orange)	✔ (green)	✔ (green)	✘ (red)
	Wi-Fi control	✔ (orange)	✔ (green)	✔ (green)	✘ (red)	✔ (green)	✔ (green)	✘ (red)
	Inverter/CT signal	✔ (green)	✘ (red)	✔ (green)	✔ (orange)	✔ (green)	✔ (green)	✘ (red)
	HEMS	✔ (orange)	✔ (green)	✔ (green)	✘ (red)	✔ (orange)	✔ (green)	✔ (orange)
	Smart (AI) timer	✔ (green)	✔ (green)	✔ (green)	✔ (green)	✔ (green)	✔ (green)	✘ (red)
Network controls	Ripple control	✔ (orange)	✔ (green)	✘ (red)	✔ (orange)	✘ (red)	NA	✔ (green)
	Smart meter	✔ (orange)	✔ (green)	✘ (red)	✔ (orange)	✔ (orange)	NA	✔ (green)
	DRED	✔ (orange)	✔ (green)	✔ (green)	✔ (orange)	✔ (green)	NA	✔ (green)
	External timer	✔ (orange)	✔ (green)	✘ (red)	✔ (orange)	✘ (red)	✔ (green)	✘ (red)

There is an opportunity here!

Key: ✔ (green)—Reliably provides benefit. ✔ (orange)—May provide benefit if appropriately managed. ✘ (red)—Benefit not provided or significantly compromised.

User and network controls

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- **Timers** have multiple limitations:
  - Not able to respond to price or other incentive signals
  - Must be set for 'worst case scenario' (typically high demand winter day) and not able to adapt to changing conditions (e.g. summer → winter, addition of new tenants)
  - Add 'hot water availability' risk, leading to call backs
- **Wi-Fi controls** enable manual overrides and 'back-end' monitoring and maintenance, but:
  - Require a stable Wi-Fi connection (not a given, especially for social housing)
  - Require some technical sophistication to use an app (not a given, especially for social housing)
  - Create risks associated with users both controlling and observing their hot water system
  - Do not guarantee hot water availability or minimal operating costs
- Using an **inverter signal** is potentially a good solution, but only for those with PV solar
- **HEMS** create too much complexity for housing providers
- **Network controls** generally require a separate circuit, bypassing solar self-consumption
- **Smart meters** enable load detection and 'soft' switching