

SunClick

Reporting on initial test results

1. Introduction

SunClick is a smart circuit breaker designed to help shift electricity demand to when solar is present in the grid, by intelligent control of resistive electric hot water heaters. It helps reduce household electricity costs, reduce the need for solar curtailment by operating when voltages are highest, and supports grid reliability by avoiding operating when voltages are lowest.

It does this using dynamic control based on local voltage data, time of day, power prices (if applicable), and learned system behaviour, tuning the device to suit individual site conditions.

This report provides a brief overview of the process and initial findings from a program to test and evaluate a prototype SunClick device.

2. Testing

The intention of the trial was to investigate whether the SunClick prototype could successfully shift water heater load to periods of the day when voltages are higher and solar is available in the grid without impacting user experience.

The trial consisted of three tests at a two-person household with a 3.6 kW resistive electric water heater, and a 5 kW solar PV system in a medium-density suburb in Melbourne, Australia. Testing was conducted between May and August 2026, and all testing apart from Test 1 occurred in Winter.

The three tests were:

1. Baseline system behaviour by running with no control other than the heater thermostat.
2. Emulating simple timer control
3. SunClick control

2.1. Test 1: No Control, to baseline system behaviour

Observing the behaviour of the trial location's water heater in the absence of any additional control.

The water heater cycled 2-5 times a day (see Figure 1). The average voltage while the hot water system running was ~3 V lower than total average voltage over the sampled period, mostly due to the drop in local voltage directly resulting from the water heater running.

The average voltage while the hot water system was running during this test was in the lowest 10th percentile of total voltages recorded during the test (4.1), and roughly 12% of the power used by the water heater in this test was from the solar PV system at the premises (4.5).

2.2. Test 2: Simple timer control

Observing the behaviour of the trial location's water heater when the SunClick device emulates a simple timer controller – turning on at 11:00 am and turning off at 2:00 pm each day.

The hot water system cycled up to 2 times in each permitted window, but typically only once. The water heater can be seen always operating in the first part of the permitted window (Figure 2 - Simple Timer Control).

The impact on local voltage of the water heater turning on and turning off can be seen in Figure 2 – local voltage drops by an average 1.8 V when the system starts to run, and climbs by an average 3.3 V when the system turns off. The average voltage while the hot water system was running during this test was in the lowest 17th percentile of total voltages recorded during the test (4.2), and roughly 24% of the power used was from the solar PV system at the premises (4.5).

Using this control approach, the hot water system does not operate when the voltage is at its peak for any of the days measured (Figure 2), and its operation contributes to the minimum voltage recorded for this test. Even in this short test period, there is variation in when voltage highs and lows occur each day, which the timer control cannot adapt to.

2.3. Test 3: Initial trial control

Running a SunClick control test that uses local voltage to determine when the water heater should be permitted to run. This test allowed the water heater to run when local voltage was above the 90th percentile value, with that threshold voltage calculated based on a moving average window, with supporting logic around hysteresis, daylight hours, and a minimum run time.

The hot water system typically cycled once per day, but in one of the days in the sampling period cycled five times (Figure 3) – the logic in the controller maintains a minimum cycle duration time, preventing more rapid toggling. The voltages recorded while the hot water system was on in this test did not contribute to the minimum or maximum voltages recorded during the test (see Table 3).

The average voltage while the hot water system was running during this test was in the 50th percentile of total voltages recorded during the test (4.3), and roughly 60% of the power used was from the solar PV available at the premises (4.5).

As with the previous two tests, there was no noticeable impact on hot water availability.

3. Conclusions

A comparison of the minimum, average, and maximum voltages recorded for each test (both general voltages, and voltages recorded when the water heater was running) is shown in Figure 5. All three tests show a reduction in maximum voltage recorded while the water heater is on (reductions of 6.4 V, 3.8 V, and 4.8 V, respectively), partly due to the voltage dip that running the water heater causes.

In both Test 1 and Test 2, the water heater's running contributed to the minimum voltage recorded for the test (see 4.1 & 4.2), but in Test 3 - i.e. SunClick control – it did not (4.3). The minimum voltage recorded in Test 3 while the water heater was running was 3.5 V above the overall minimum (4.3), and SunClick control avoided all periods of low voltage in the recorded window (see Figure 3), contributing to grid stability.

The average voltage recorded while the water heater ran under SunClick control was 0.22 V higher than the average voltage recorded during the test (4.3) - a small increase, but this was the only control method where an increase occurred. In Test 1 there was a 3.26 V decrease (4.1), and in

Test 2 a 1.93 V decrease (4.2), in part due to the local voltage dip that occurs when the water heater runs.

The main aim of this test was to shift the operation of the water heater to the periods of the day with higher voltages, and so increased likelihoods of available solar power. This test has shown a successful shift, both in voltage values and in the proportion of power consumed by the water heater that came from available solar power.

While it was controlled by SunClick, the average voltage recorded while the water heater was running was in the 50th percentile of voltages recorded during the test – compared to the 10th percentile and 17th percentile equivalent figures for Tests 1 and 2, respectively (4.1, 4.2). SunClick also increased the proportion of water heater power that was from the test site's installed solar system – from 12% in the uncontrolled case and 24% in the timer-controller case, to 60% when controlled by SunClick (4.5). This was without any direct integration with the solar inverter at the site – just from targeting periods with higher voltages.

The relatively low proportion recorded for the timer-controlled case (Test 2) is in part due to the date of the test (19th – 22nd June, 2026), compared to the dates for Test 1 (19th May – 24th May, 2026) and Test 3 (31st July – 4th August, 2026). This report is not making a comment on the proportion of solar power that it's possible to achieve via simple timer control of an electric water heater, only that this was the proportion recorded under these test conditions – refer to 4.5 for more detailed comments on what impacted these results. While it's possible that a test could be conducted in ideal conditions where both a timer-controlled water heater and a SunClick controlled water heater could be 100% covered by the solar power available at the site, a key aspect that these tests have demonstrated is that even in these short windows, significant day-to-day variation can occur, impacting voltage patterns and solar availability, which SunClick can adapt to effectively.

This test shows positive initial results, confirming SunClick's potential to shift a resistive electric water heater's load to make better use of available solar power by targeting higher local voltages. With development of the logic and the site-specific tuning of the control, results can be improved further. Following these results, continued testing will look at results over a longer period, to observe system behaviour in a greater variety of grid conditions.

4. Appendices

4.1. Test 1 Data - No Control

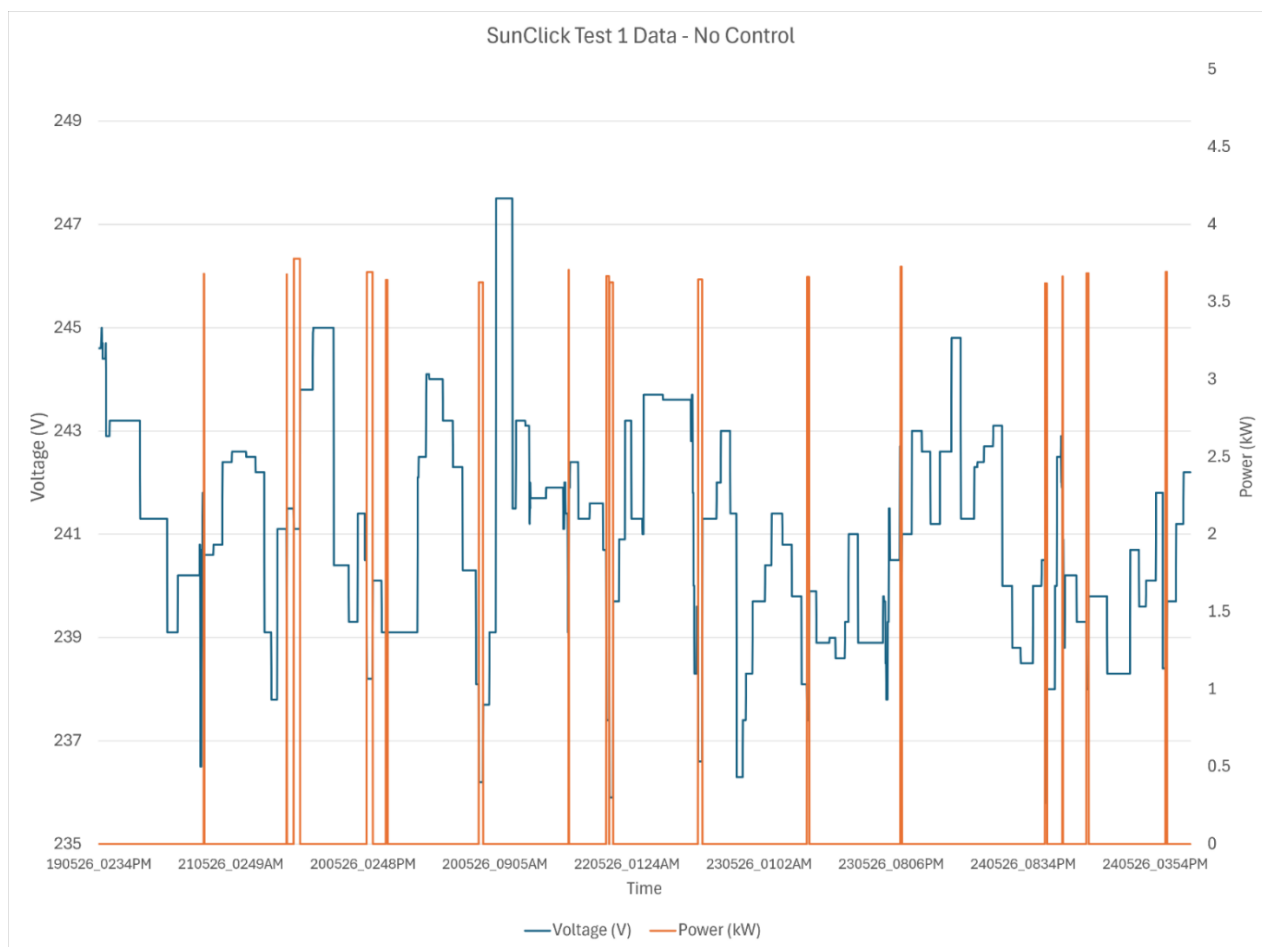


Figure 1- Test 1 Data, no control

Note that there is no 'device status' shown in this graph, because for Test 1 the water heater circuit was always powered.

Table 1- Test 1 Minimum, Average, and Maximum Voltages

	Minimum	Average	Maximum
Voltage	235.8	241.1	247.5
Voltage while HW system is running	235.8	237.8	241.1

During this test, the water heater contributed to the minimum voltage recorded.

While the hot water system was running during this test, its average voltage was in the 10th percentile of the full set of voltages recorded during the test:

- Minimum voltage was in the 0th percentile (i.e. the lowest voltage recorded)
- Average voltage was in the bottom 10th percentile
- Maximum voltage was in the 49th percentile.

Refer to 4.5 for solar power contribution during this test.

4.2. Test 2 Data - Emulating Timer Control

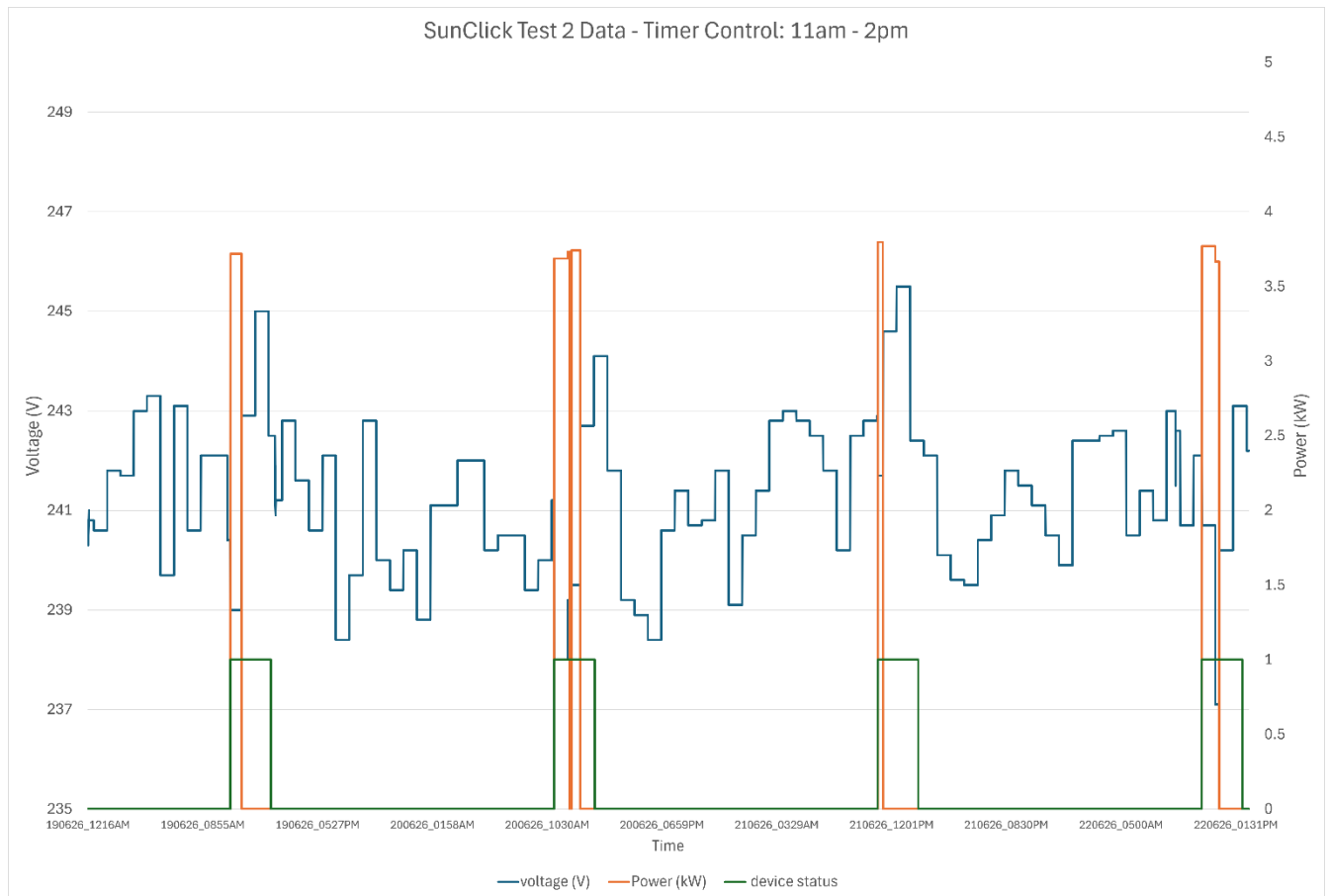


Figure 2 - Simple Timer Control

Table 2: Test 2 Minimum, Average, and Maximum Voltages

	Minimum	Average	Maximum
Voltage	237.1	241.3	245.5
Voltage while HW system is running	237.1	239.4	241.7

During this test the water heater contributed to the minimum voltage recorded, as it did in Test 1.

While the hot water system was running during this test, its average voltage was in the bottom 17th percentile of the full set of voltages recorded during the test:

- Minimum voltage was in the 0th percentile (i.e. the lowest voltage recorded)
- Average voltage was in the bottom 17th percentile
- Maximum voltage was in the 56th percentile.

Refer to 4.5 for solar power contribution during this test.

4.3. Test 3 Data - SunClick Control

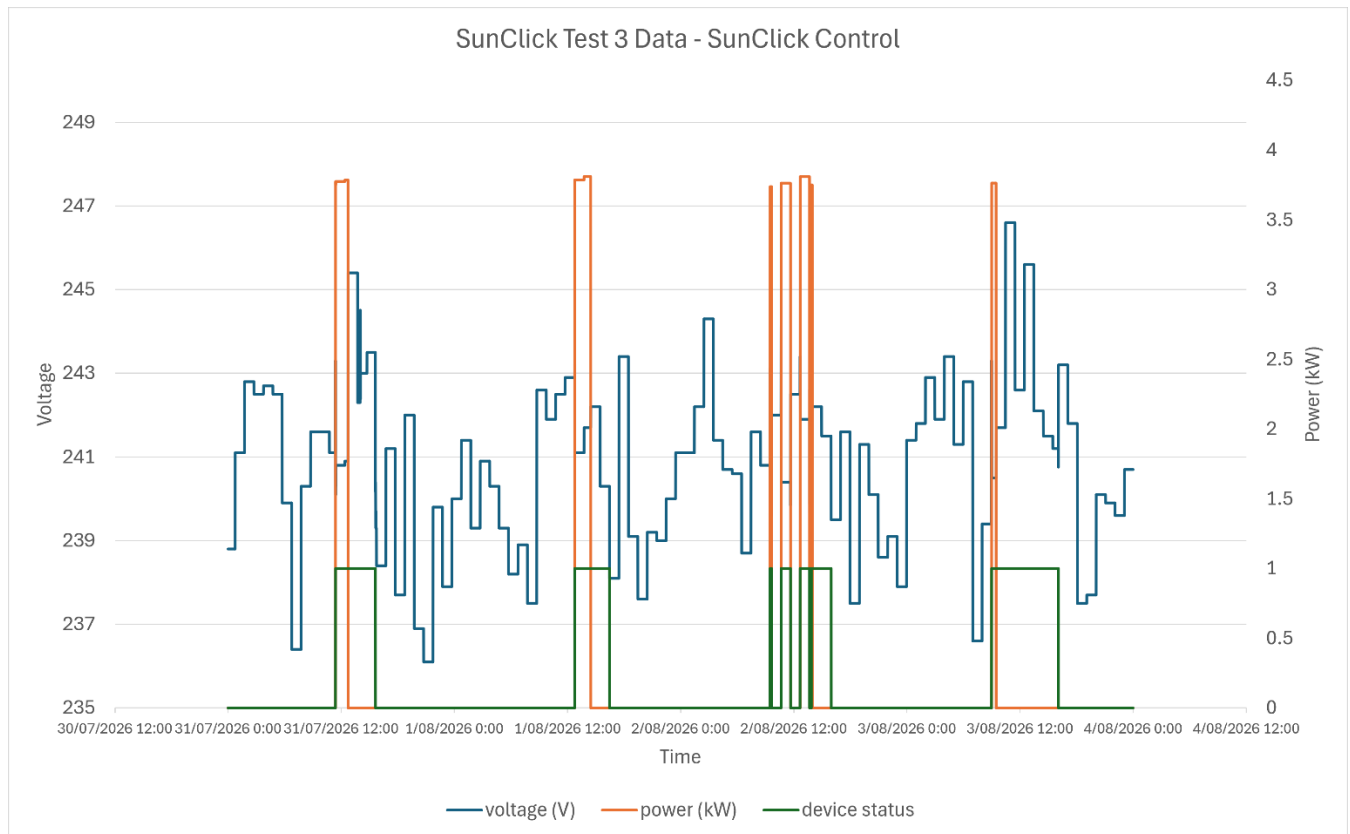


Figure 3 - Test data from initial control trial

Table 3- Test 3 Minimum, Average, and Maximum Voltages

	Minimum	Average	Maximum
Voltage	236.10	240.75	246.60
Voltage while HW system is running	239.60	240.97	241.90

Unlike the in previous two tests, voltages recorded while the hot water system was running did not contribute to the minimum voltage recorded.

While the hot water system was running during this test, its average voltage was in 50th percentile of the full set of voltages recorded during the test:

- Minimum voltage was in the bottom 28th percentile
- Average voltage was in the 50th percentile
- Maximum voltage was in the 70th percentile

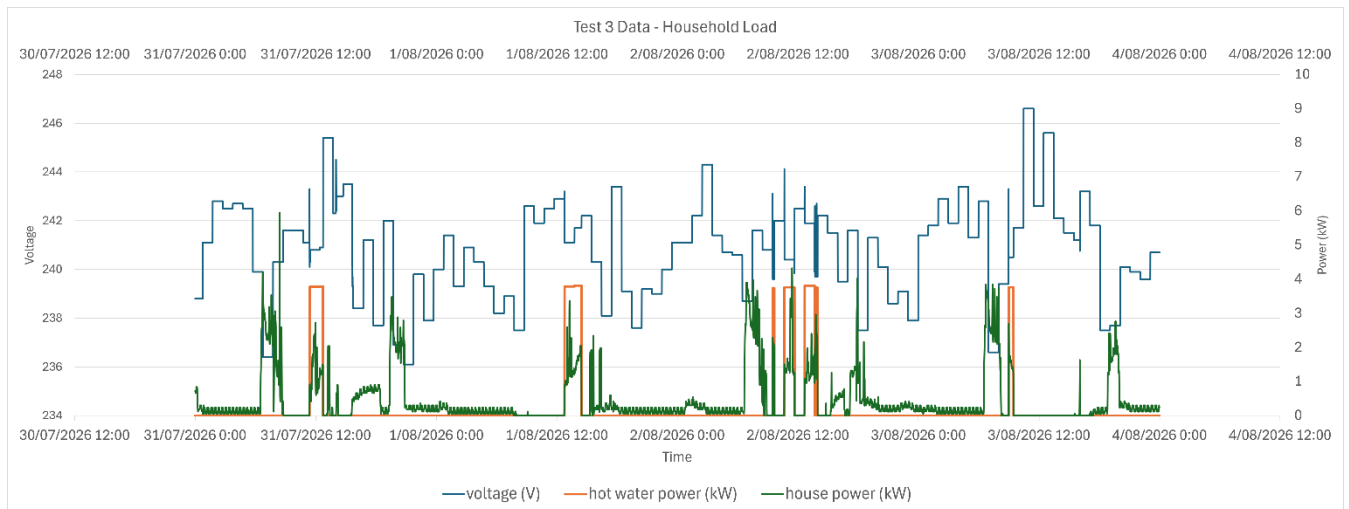


Figure 4 - Test 3 Voltage and Power vs Household Power Usage

The graph above shows the same voltage and power traces in Figure 3, with the addition of total household electrical power, which includes the contribution from rooftop solar installed at the premises - periods of time showing zero house power usage (*house power (kW)*) correspond to when there was a net export of solar power. Each of the instances of the hot water system running (*hot water power (kW)*) can be seen occurring in these periods, demonstrating that SunClick has successfully timed the hot water system's running to coincide with solar availability.

The extent to which the hot water system used solar power behind the meter is shown in the gap between these two traces - Refer to 4.5 for more detail on the solar power contribution during this test.

The graph also shows most periods of higher voltage coinciding with periods of low household power consumption and/or solar generation.

4.4. Additional Data Analysis – Voltage Comparisons

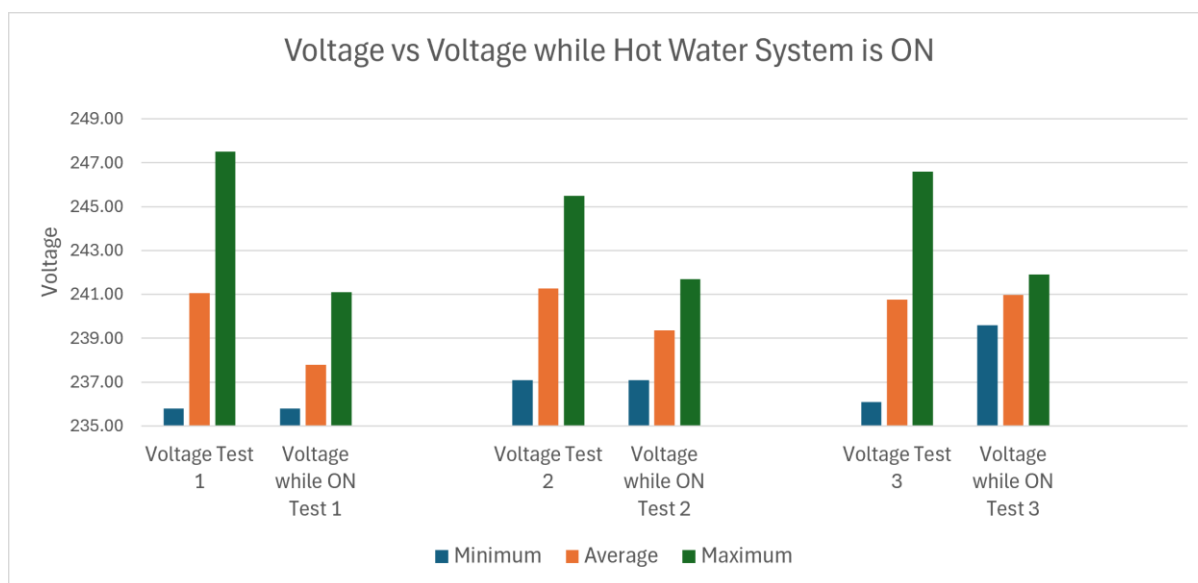


Figure 5: Voltage comparisons for tests 1-3

The chart above shows the minimum, average, and maximum voltages recorded for each test – both for the total sampling period, and for the subset of the test where the water heater was running. A small dip (~3V) in average and maximum voltages can be attributed to the voltage dip that directly results from the water heater running.

Both Test 1 and Test 2 show no change to minimum voltage, which shows that the water heater was partially responsible for the minimum voltage. Test 3 shows a 3.5 V increase in minimum voltage recorded while the hot water system was on.

On the difference in average voltages recorded:

- Test 1 shows a 3.26V decrease in average: largely attributed to the voltage dip that the hot water system cause.
- Test 2 shows a 1.93V decrease – in part due to the voltage dip from the water heater, but lessened by targeting the 11am – 2pm range where voltages were higher on average.
- Test 3 is the only test to show an increase in average voltage – 0.22V.

4.5. Additional Data Analysis – Solar Contribution

For the purposes of this test, solar contributions to the water heater are only counted after any other household loads. For example:

- If the water heater is using 3.6 kW, general household loads are using a total of 1.5 kW, and solar is providing 1.0 kW:
 - Net household load will be recorded as 4.1kW ($3.6 + 1.5 - 1.0$)
 - This test would count this as solar contributing 0 kW towards the water heater's running.

- If the water heater is using 3.6 kW, general other household loads are using a total of 1.5 kW, and solar is providing 4.0 kW:
 - Net household load will be recorded as 1.1 kW ($3.6 + 1.5 - 4.0$)
 - This test would count this as solar contributing 2.5 kW towards the water heater's running, or 69.4% of the water heater power.
- If the water heater is using 3.6 kW, general household loads are using a total of 1.0 kW, and solar is providing 5.0 kW:
 - Net household load will be recorded as 0 kW ($3.6 + 1.0 - 5.0$, but negative/export values are not recorded by the installed equipment)
 - This test would count this as solar contributing 3.6 kW towards the water heater's running, or 100% of the water heater power.

Any net household load recorded that is *above* the water heater power consumption indicates that on-site solar power is not contributing to the water heater – either because there is no on-site solar power available, or because other household loads have used it. However, any household load measurement above water heater power is not relevant to the solar proportion – it can't be lower than 0% - so individual net household load measurements have been capped at a maximum value that aligns with the actual power consumption of the water heater.

This understates the solar contribution compared with just allocating the solar electricity proportionately to all loads, but this conservative approach is reasonable considering the water heating can be time-shifted and so is a lower priority electrical load.

Test 1 – Uncontrolled Baseline

- The average power of the water heater during this test was 3.68 kW, recorded at 30s intervals.
- The average net household power use over the same time periods – recorded at 60s intervals and capped at a 3.68 kW maximum for individual measurements – was 3.25 kW
- The gap between these two measurements represents the estimated amount of solar power contributing to running the water heater during this test:
 - $3.682 - 3.247 = 0.435$ kW
 - $0.435 / 3.682 = 0.118 \rightarrow 12\%$

Note: this baselining test was conducted over 6 days, from the 19th of May to the 24th of May, where Melbourne had an estimated 9:52 to 10:00 daylight hours per test day¹. Testing over a longer period would form a more accurate baseline for what proportion of the water heater power would typically come from solar at this specific site, as well as general variation in household load. Seasonal shifts and weather conditions would also have an impact – this test was not intended to cover all possible scenarios for the uncontrolled water heater case, but to capture a snapshot of what the results can be.

Test 2 – Simple Timer Control

- The average power usage of the water heater during this test was 3.73 kW, recorded at 30s intervals.

¹ <https://www.timeanddate.com/sun/australia/melbourne?month=5&year=2026>

- The average net household power use over the same time periods – recorded at 60s intervals and capped at a 3.73 kW maximum for individual measurements – was 2.82 kW
- The gap between these two measurements represents the estimated amount of solar power contributing to running the water heater during this test:
 - $3.730 - 2.819 = 0.911 \text{ kW}$
 - $0.911 / 3.730 = 0.244 \rightarrow 24\%$

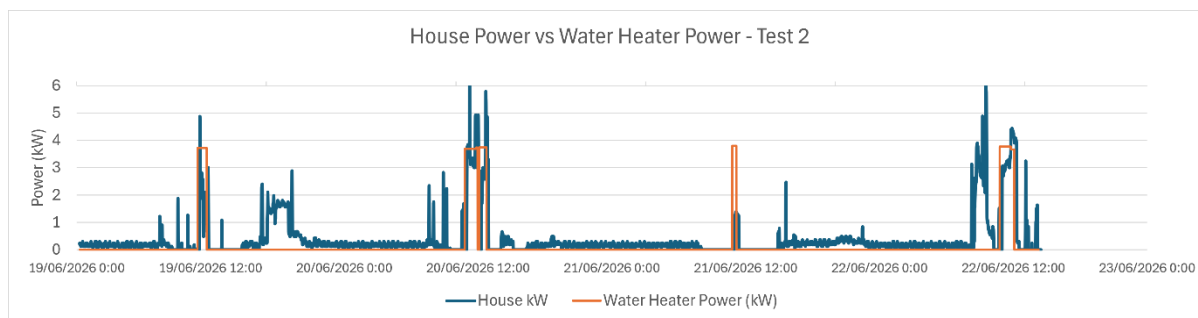


Figure 6 - House Power vs Water Heater Power - Test 2

Note: this report is not stating what proportion of water heat power *can* be provided by on-site solar power when controlled by a simple timer – under different conditions this proportion could be much higher - only that this is what was recorded under the conditions of this test.

Seasonal changes would have an impact: this test was conducted from the 19th – 22nd of June in Melbourne, with ~9:32 daylight hours per test day². In any other season, this proportion should be higher. The size of the solar installation would also impact the figure – the installation at the test site is 5 kW, which did not change across the three tests. A larger installation would contribute a higher proportion of water heater power.

Household load pattern changes would also impact results – this was not a pristine test environment, and normal life continued in the two-person household that was the test site for the duration of the tests. In general, there were no major changes in consumption habits for the testing.

For this test specifically, the timer settings could be tuned to suit the specific site. Based on what has been observed in this test, for this installation site, a later start time could increase the proportion of solar power for the water heater. The timer settings used for this test (11:00 am – 2:00 pm) were selected because they were the timer settings that had been in use at this site for the previous year - based on the recommendation of the installer at the time - and so were considered a fair representation for a snapshot of timer performance.

Test 3 – SunClick Control

- The average power usage of the water heater during this test was 3.78 kW, recorded at 30s intervals.
- The average net household power use over the same time periods – recorded at 60s intervals and capped at a 3.78 kW maximum for individual measurements – was 1.51 kW

² <https://www.timeanddate.com/sun/australia/melbourne?month=6&year=2026>

- The gap between these two measurements represents the estimated amount of solar power contributing to running the water heater during this test:
 - $3.783 - 1.511 = 2.272 \text{ kW}$
 - $2.272 / 3.783 = 0.601 \rightarrow \mathbf{60\%}$

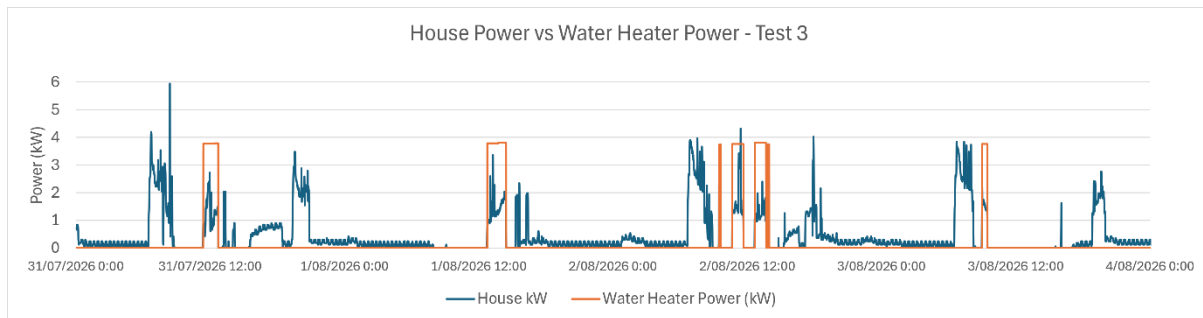


Figure 7 - House Power vs Water Heater, Test 3

This test was conducted from the 31st of July – 4th August, 2026, with an estimated 10:10 – 10:17 hours of daylight per test day³, giving Test 3 results a small advantage over Test 2.

Some of the points noted above that would impact the results for the timer-controlled case would have a similar impact on the SunClick case – like seasonal impacts and the size of the installed solar system.

³ <https://www.timeanddate.com/sun/australia/melbourne?month=7&year=2026>