Hotter is Not Always Better - Impacts of HPWH Settings on Load Shifting Performance

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ABSTRACT

As California's electricity mix continues to evolve toward higher penetrations of solar and other variable renewables, the need for demand-side flexibility is increasingly critical. Daily mismatches between renewable generation and customer demand are driving the need for distributed resources that can shift load cost-effectively and predictably. Flexible electric end uses, particularly those capable of storing thermal energy, offer a scalable pathway to improving grid reliability while supporting decarbonization goals.

Heat Pump Water Heaters (HPWHs) are particularly well suited for this role. By leveraging water as a thermal battery, HPWHs can shift electricity use to align with renewable availability without impacting customer comfort. The emerging practice of Advanced Load Up (ALU) that temporarily increases tank temperature during periods of high renewable generation ahead of peak demand periods, further enhances this flexibility potential. However, variations in equipment configuration, temperature setpoints, and control strategies significantly affect both energy performance and achievable load shift, influencing customer costs and overall grid benefits. Using operational data from WatterSaver, which has been orchestrating daily load shifting across hundreds of HPWHs since 2022, this paper examines how different configurations affect energy use and grid impacts. We analyze how temperature setpoints, ALU capabilities, and customer satisfaction interact to identify design and control strategies that maximize overall system value.

Our findings can inform best practices for HPWH installations and control strategies, highlighting the importance of ALU in unlocking HPWHs' full flexibility potential. Recommendations are provided to maximize both customer satisfaction and the grid value of future HPWH deployments.

Introduction

As a result of California's legislative and regulatory efforts to accelerate the electrification of the built environment and increase the use of renewable energy, particularly solar photovoltaic (PV), the state is experiencing a deepening of the duck curve (Figure 1). To mitigate this phenomenon the state increased its efforts to install energy storage capacity, thus adopting Assembly Bill 2868 (Gatto, 2016) which required the California Public Utilities Commission (CPUC) to direct the state's three electric investor-owned utilities to invest in the deployment of distributed energy storage systems. As a result of AB 2868, Pacific Gas and Electric Company (PG&E) proposed a behind-the-meter thermal energy storage pilot program called WatterSaver (the program). The pilot program was conditionally approved by the CPUC in June 2019. The Association for Energy Affordability (AEA) partnered with Energy Solutions and Virtual Peaker (the implementation team or the team) to bid on PG&E's subsequent request for proposal, and the team was selected to implement the program in December 2019. Phase one of the program (WSP1) concluded on December 31, 2025.

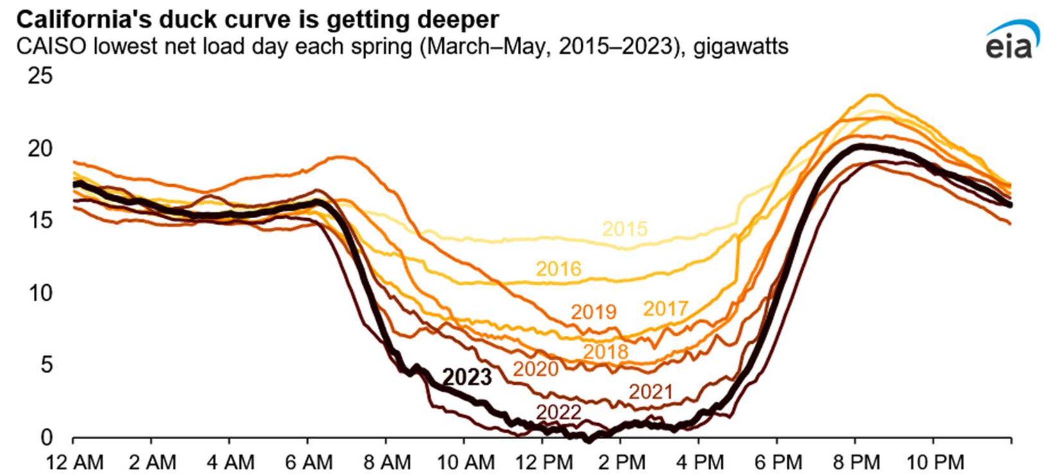

Figure 1. CAISO lowest net load day each spring (gigawatts, March-May, 2015-2023).
Source: EIA 2023 (figure), CAISO (data)

WSP1 enrolled customers from March 2022 through October 2025 and signaled daily load shifting activities from March 28, 2022, to December 23, 2025. Customers were placed in different load shifting groups based on the type of water heater (e.g. HPWH or electric resistance water heater), the presence of a thermostatic mixing valve (TMV), the ability of the water heater to respond to ALU commands, and the customer's electricity rate (Besson et al. 2024). The program offered two types of load ups: ALU – heating water to a temperature higher than the customer setpoint – and basic load up (BLU) – heating water to the customer setpoint. Modifications were made to the ALU parameters over time. Using available HPWH data and focusing on customers with a peak rate from 4pm to 9pm, this publication looks at the impact of customer and command settings on load shifting results.

Background

HPWH Connection and Data Collected

WatterSaver is a large-scale demonstration pilot working with commercially available technology. It uses a single distributed energy resources management system (DERMS) that integrates with both HPWH manufacturers' proprietary application programming interface (API) and CTA-2045[1] universal communication modules (UCM) API. The program does not add

[1] CTA-2045 (ANSI/CTA) is a modular communication interface standard, describing both a physical interface (port) and communication protocol for energy management.

additional monitoring equipment to participants' HPWH. As a result, the program only has access to the data made available by the DERMS provider, which in turn depends on the data made available by the HPWH and UCM manufacturers. It is important to note that not all data made available by manufacturers is collected and transferred by the DERMS provider. Table 1 summarizes the data available to the program based on how the HPWH is connected to the program.

Table 1. Data available to the program per connection type

Data	Description	HPWH manufacturer API	CTA-2045 UCM
Power	Instantaneous power consumption – some manufacturers use estimated static numbers in lieu of measured variable power	Yes	Yes
Present Take Capacity	Amount of energy needed to bring the HPWH from its current temperature to its setpoint	No	Yes
Maximum Take Capacity	Amount of energy needed to bring cold water to the HPWH setpoint	No	Yes
Advanced Present Take Capacity	Amount of energy needed to bring the HPWH from its current temperature to the maximum ALU setpoint	No	Yes
Advanced Maximum Take Capacity	Amount of energy needed to bring cold water to the HPWH maximum ALU setpoint	No	No
Setpoint	Target tank temperature	Yes	No
Temperature	Actual tank temperature	Manufacturer dependent	No
Efficiency Level	Indicates the likelihood of resistive element usage, from Heat Pump only to Electric Resistance only	Yes	No
Curtailment Type	Indicates the type of event the HPWH is in (Normal/no event, Load Up, ALU, Shed, Critical Peak, Grid Emergency)	No	Yes

Maximum Take Capacity is directly related to the HPWH setpoint, as well as tank size. The exact equation varies by manufacturer. AEA was not able to gather sufficient information to allow the mapping of the different combinations of Maximum Take Capacity and setpoint. For this reason, this publication will use data from HPWH connected via manufacturer API only.

Load Shifting Commands

The WatterSaver program uses a signaled approach to control water heaters, where the program implementer uses the DERMS provider interface to create a schedule and dispatch commands. The program's command names are the same as the ones listed in the CTA-2045 standard (ANSI/CTA). The exact water heater response to any given command results from a control algorithm defined by Original Equipment Manufacturers (OEMs) (Butzbaugh et al. 2022, Paresa and Bass, 2024) and/or the DERMS provider, and thus the HPWH responses to load shifting commands are custom to each OEM and connection type.

Initially, the implementer only had access to one load up command. The observed behavior would depend on the indication of the presence of a TMV on the installation. If the TMV indicator was off, no changes would be made to the HPWH setpoint. If the TMV indicator was on, the HPWH setpoint was adjusted to 140 °F, regardless of the customer setpoint. In December 2024, the DERMS provider implemented a modification to its load shifting command to align more closely with the CTA-2045-B standard. Since that modification, the implementer has access to two separate load up commands:

- ALU: implementer specifies the temperature setpoint increase (required) and efficiency mode (optional). It is important to note that the setpoint cannot exceed the maximum allowed by the OEMs. For the HPWHs used in this publication, that maximum is 140 °F.
- BLU: no change to the customer setpoint or efficiency mode.

Table 2. Observed response to commands used by WatterSaver for HPWH connected via manufacturer API

<table>
<tr><th>Command</th><th>Before December 2024</th><th>After December 2024</th></tr>
<tr><td>Advanced Load Up (if applicable)</td><td rowspan="2">One Load Up command, behavior dependent on TMV presence indicator:
TMV present: temperature setpoint adjusted to 140 °F,
No TMV: temperature setpoint remains the same,
No change in efficiency mode</td><td>Implementer specifies temperature setpoint increase, no higher than 140 °F (maximum allowed by OEMs),
Implementer specifies efficiency mode</td></tr>
<tr><td>Basic Load Up</td><td>Temperature setpoint remains the same,
No change in efficiency mode</td></tr>
<tr><td>Shed</td><td>Setpoint decreased by 10 °F, no lower than 110 °F (minimum allowed by OEMs),
Recovery allowed,
No change in efficiency mode</td><td>Unchanged</td></tr>
</table>

Load Shifting Schedules

The load shifting schedules offered by the program consist of a load up phase using the BLU or ALU command followed by a curtailment phase using the Shed command. The duration of the curtailment depends on the customer's electricity rate. The duration of load up varied over time. It was initially set to 2 hours for all cohorts. In 2024, the load up durations were adjusted based on load up command and curtailment duration:

- Cohorts receiving BLU commands had a 1-hour load up period, regardless of curtailment duration.
- The cohort receiving an ALU command followed by a 5-hour curtailment had a 2-hour load up period,
- The cohort receiving an ALU command followed by a 9-hour curtailment had a 3-hour load up period.

As stated previously, this publication will focus on the cohorts with a 5-hour curtailment.

Table 3. Load shifting schedules by program year, 2022-2025

	2022-2023	2024	2025
BLU 4-9	BLU: 2pm to 4pm Shed: 4pm to 9pm	BLU: 3pm to 4pm Shed: 4pm to 9pm	BLU: 3pm to 4pm Shed: 4pm to 9pm
ALU 4-9	ALU (140 °F setpoint, no efficiency mode change): 2pm to 4pm Shed: 4pm to 9pm	ALU (140 °F setpoint, no efficiency mode change): 2:15 pm to 4pm Shed: 4pm to 9pm	ALU (+10 °F, heat pump mode): 2pm to 4pm Shed: 4pm to 9pm

Methodology

Baseline

To evaluate the pilot impact, the team implemented a randomized control trial (RCT) protocol. Each day at midnight, 10% of devices in active platoons with more than 35 water heaters were set aside and did not receive commands for the day. These numbers (10% and 35 devices) were chosen to balance the need for a baseline to measure the program impact while minimizing the impact on aggregate load shifting results. The baseline protocol has been in place since March 17, 2023 for the 4-9 Shed ALU and 4-9 Shed BLU cohorts.

Additionally, load shifting impacts water heater behavior beyond the Load Up and Shed phases, sometimes into the early hours of the day following an event. For that reason, we look at data from 10 am to 9:59 am the next day. For example, if a water heater was in the active group on April 30, 2025, and is placed in baseline on May 1, 2025, data from April 30, 2025, 10 am to May 1, 2025, 9:59 am will be used for the active group and data from May 1, 2025, 10 am to May 2, 2025, 9:59 am will be used for baseline.

Load Shifting Participation

The dataset was filtered to keep only data from HPWHs that successfully participated in both the load up and the curtailment events on any given day.[2] A pairing filter was applied to ensure that both baseline and active dataset contained the same HPWHs over the time period of the analysis, e.g. if a HPWH had baseline days but no successful load shifting days over the analyzed time period, its data was excluded from the baseline dataset; similarly, if a HPWH had successful load shifting days but no baseline days over the analyzed time period, its data was excluded from the active dataset.

Impact of HPWH Settings

TECH Clean California was a statewide initiative driving the adoption of heat pump technology for water heating and space conditioning that included incentive programs and had been an important source of customers for WatterSaver. Starting October 31, 2023, TECH Clean California required the HPWHs installed through the program be time of use (TOU) optimized at time of installation. This means the installer selected a schedule based on the customer's electricity rate at time of installation (Barsun et al. 2026, Kehmeier et al. 2026). And starting December 10, 2024, TECH Clean California required enrollment in a demand flexible water heater rewards program such as WatterSaver where available. As a result, WatterSaver saw a large influx of participants whose HPWHs were TOU-optimized. To isolate the impact of customer settings and load shifting command parameters, TOU-optimized devices have been removed from the dataset for this publication. Results about the differences between scheduled TOU optimization and signaled load shifting by a program like WatterSaver can be found in Barsun et al. (2026).

For the analysis by setpoint, for each day, we identified the HPWHs' setpoint at 10am and used this information to parse both the active and baseline datasets. For the performed BLU vs performed ALU analysis, the data was parsed as follow:

- Performed BLU consists of all HPWHs receiving a BLU command and HPWHs with a 140 °F temperature setpoint receiving an ALU command. Note that HPWHs already at the OEMs' maximum setpoint of 140 °F could not be heated above this setpoint when an ALU command was received.
- Performed ALU consists of all HPWHs receiving an ALU command with a temperature setpoint strictly below 140 °F.

The user-selected efficiency mode impacts the resistive element (RE) usage. RE utilization is based on internal logic set by the manufacturers that revolves around temperature difference from setpoint and varies based on the efficiency mode selected. Heat Pump mode is

[2] Note that a portion of HPWHs (10-20%) did not respond to load shifting signals on any given day due to communication issues, customer opt out, or HPWHs being on vacation mode,

the least likely to trigger the RE, High Demand is the most likely to trigger it and Hybrid mode is intermediate. The program does not control participants' efficiency mode outside of load shifting events. As a result, this publication will only look at the impact of controlling efficiency mode during load shifting events, especially during ALU.

Load Profile

In this publication, we will be using population-based averages profiles. For the impact of user setpoint on baseline analysis, we used data from the entirety of the program duration, from March 2022 through December 2025. To isolate the impact of user setpoint on load shifting results from the changes in load up command algorithm, we used 2025 data only for that analysis. The number of unique devices and number of days of data for the different profiles used in this publication are summarized in Table 4.

Table 4. Number of unique devices and days of data used in the different analysis

Profile group based on signal type and user setpoint	Number of unique devices	Days of data load shifted	Days of data baseline
Baseline (no signal) 110 °F	157	N/A	1,714
Baseline (no signal) 120 °F	291	N/A	5,013
Baseline (no signal) 130 °F	169	N/A	2,208
Baseline (no signal) 140 °F	183	N/A	2,117
ALU 110 °F	39	3,234	444
BLU 110 °F	43	3,991	507
ALU 120 °F	78	8,797	1,112
BLU 120 °F	86	10,719	1,374
ALU 130 °F	55	5,063	794
BLU 130 °F	15	1,827	216
ALU 140 °F	47	4,116	599
BLU 140 °F	6	806	102
Performed ALU[3]	168	24,985	3,459
Performed BLU[3]	197	31,073	4,319

Green House Gas Emissions and Grid Impact

Green House Gas (GHG) emissions and grid impacts are calculated using hourly 8760 GHG content from California's electrical grid and annualized hourly grid costs respectively, both from the CPUC avoided cost calculator (ACC).

[3] Performed ALU and performed BLU include devices with intermediate temperature setpoint that are not captured in the previous groups (i.e. devices with a 125 °F setpoint are captured in the performed groups).

Results

Impact of User Setpoint on Baseline

HPWH laboratory performance evaluations (B. Sparn et al. 2014) have shown the impact of temperature setpoint on coefficient of performance (COP), where higher temperature setpoint results in lower COP and higher energy use. When comparing WatterSaver results (Figure 1) to these laboratory results (Table 5), WatterSaver observed increases in energy usage are mostly higher, with the exception of the comparison between 130 °F and 140 °F temperature setpoint. For example, based on laboratory results, the COP impact of increasing a HPWH temperature setpoint from 120 °F (Table 5 row) to 130 °F (Table 5 column) is a 12% increase in energy use, where WatterSaver observes a 21% increase. Several factors can explain this difference, including increased standby losses, higher distribution losses or a higher domestic hot water usage. Since the program does not monitor water flow, quantifying the contribution of each of these factors on energy use is not possible.

Table 5. Increase in energy consumption per setpoint

	110 °F/43 °C		120 °F/49 °C		130 °F/54 °C		140 °F/60 °C	
	Watter Saver	NREL	Watter Saver	NREL	Watter Saver	NREL	Watter Saver	NREL
110 °F /43 °C			+ 15%	+ 7%	+ 39%	+ 20%	+ 49%	+ 31%
120 °F /49 °C					+ 21%	+ 12%	+ 30%	+ 22%
130 °F /54 °C							+ 7%	+ 9%
140 °F /60 °C								

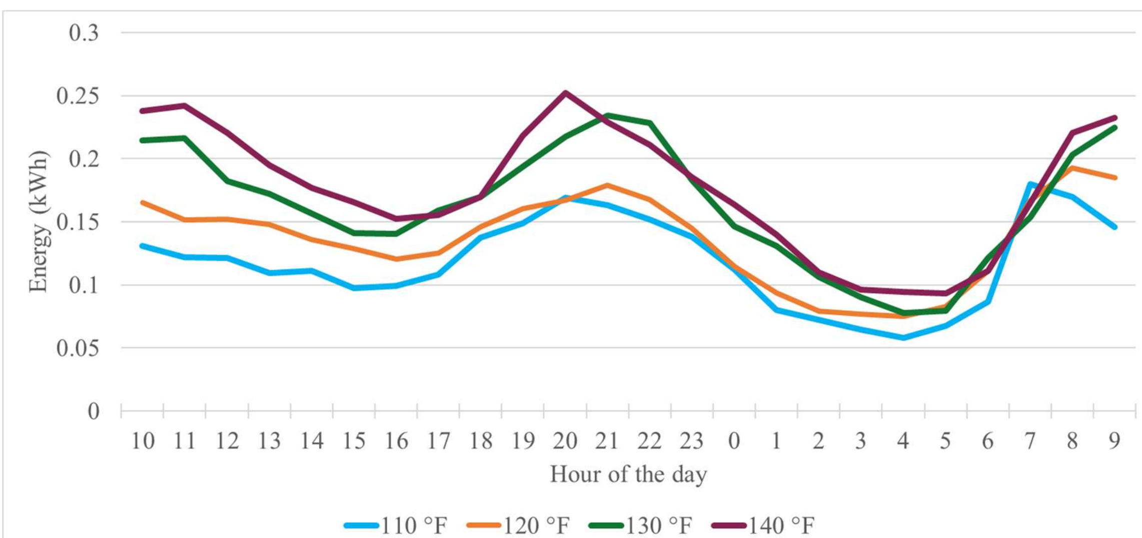

Figure 2. Daily baseline energy usage profile per user setpoint (population-based average, Mar 2022-Dec 2025).

Impact of User Setpoint on Load Shifting

The user setpoint also affects the HPWH's ability to perform load shifting. Figure 3 illustrates the differences in behavior between ALU and BLU appears clearly for participants with an intermediate setpoint such as 120 °F. In that scenario, ALU results in a significant increase in energy consumption during the Load Up phase, HPWH suppression for the full duration of the Shed, and no post-Shed snap-back. BLU results in no to limited increase in energy consumption during the Load Up phase, some HPWH recovery during the Shed phase, and a significant post-Shed snap-back.

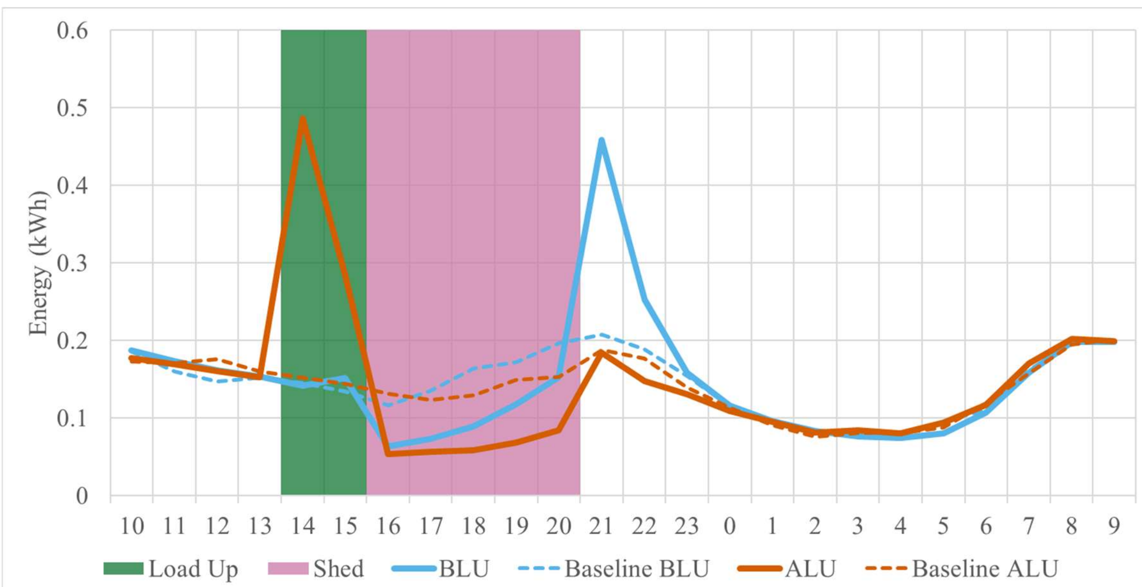

Figure 3. Daily energy usage average profile for HPWH with 120 °F user setpoint (population-based average, 2025).

If the user setpoint is already at the minimum allowed by the manufacturer, then the HPWH capacity to perform a Shed will be limited for both ALU and BLU groups, but especially under BLU since no extra energy can be stored in advance (Figure 4).

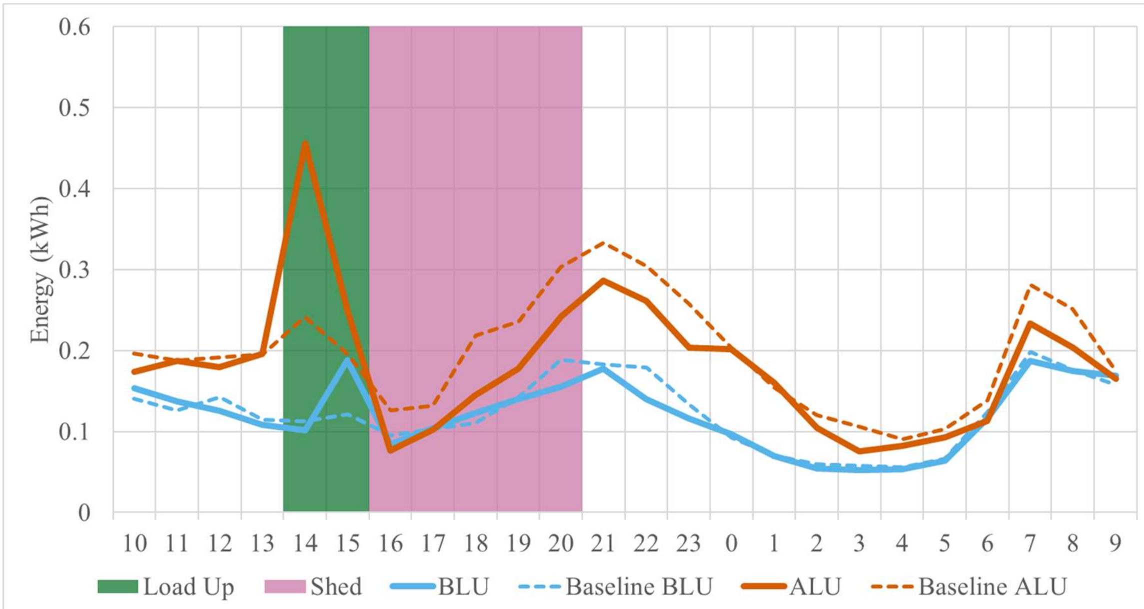

Figure 4. Daily energy usage average profile for HPWH with 110 °F user setpoint (population-based average, 2025).

If the user setpoint is at the maximum allowed by the manufacturer, then the HWPH can only perform BLU, since no extra energy can be stored during the Load Up phase. The load shape for the group of participants with a setpoint of 140 °F who received ALU commands is similar to the load shape of the group that received BLU commands during the Shed and post-Shed period (Figure 5). In other words, ALU is not an option for HPWHs whose temperature setpoints are at the manufacturer's maximum allowable temperature setpoint.

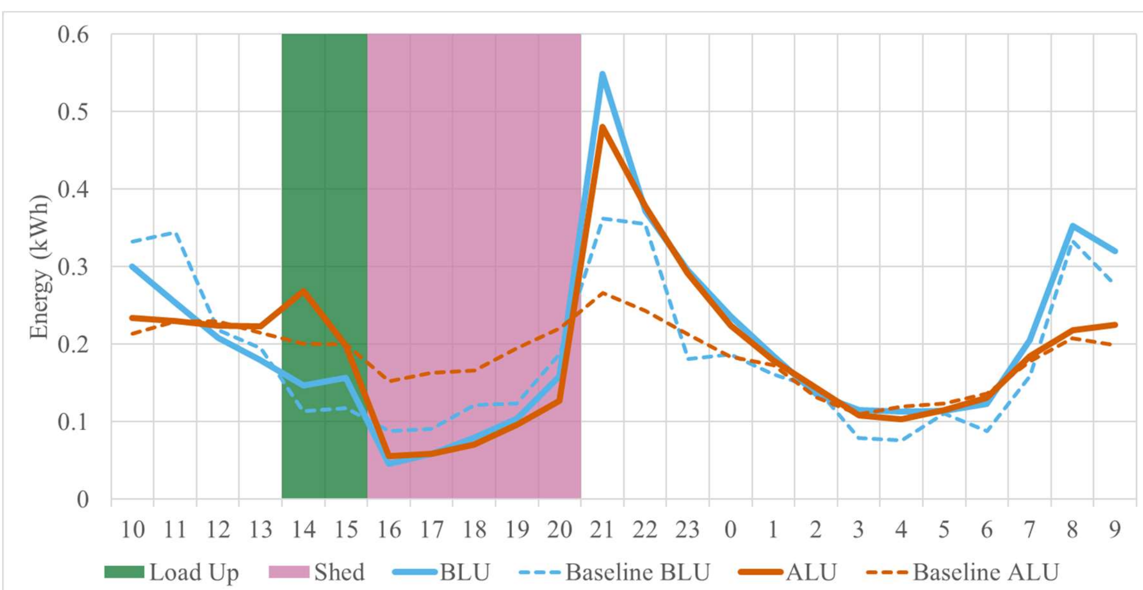

Figure 5. Daily energy usage average profile for HPWH with 140 °F user setpoint (population-based average, 2025).

The results for each of the major setpoints (110 °F, 120 °F, 130 °F and 140 °F) are summarized in Table 6 for HPWH receiving ALU commands and Table 7 for HPWH receiving BLU commands. Note that some groups have a very small sample size (n < 30, Table 4) and their results are not significant. In general, ALU results in more energy shifted out of peak period, higher GHG emissions reduction and higher grid impact.

Table 6. Load shifting results relative to baseline for HPWH receiving ALU schedule by user setpoint

	110 °F	120 °F	130 °F	140 °F
Energy Shifted to Load Up phase (2pm – 4pm, daily)	+ 0.27 kWh	+ 0.48 kWh	+ 0.56 kWh	+ 0.07 kWh
Energy Shifted out of Peak (4pm – 9pm, daily)	- 0.27 kWh	- 0.37 kWh	- 0.42 kWh	- 0.49 kWh
Energy Usage Impact	- 8%	+ 2%	+ 5%	+ 2%
GHG Impact	- 11%	- 4%	- 2%	- 0%
Grid Impact (annual)	- $25	- $20	- $25	- $30

Table 7. Load shifting results relative to baseline for HPWH receiving BLU schedule by user setpoint

	110 °F	120 °F	130 °F[4]	140 °F[5]
Energy Shifted to Load Up phase (2pm – 4pm, daily)	+ 0.06 kWh	+ 0.01 kWh	+ 0.01 kWh	+ 0.07 kWh
Energy Shifted out of Peak (4pm – 9pm, daily)	- 0.03 kWh	- 0.29 kWh	- 0.51 kWh	- 0.16 kWh
Energy Usage Impact	- 2%	+ 1%	- 4%	+ 8%
GHG Impact	- 3%	+ 1%	- 4%	+ 9%
Grid Impact (annual)	$ neutral	- $20	- $35	$ neutral

Performed ALU vs Performed BLU

As illustrated in the previous section, and documented in Besson et al. 2024, sending an ALU command will not necessarily result in a traditional ALU response, which we define as the HPWH storing additional energy as a result of an increase in setpoint compared to normal operation. In comparing performed ALU (devices with a temperature setpoint strictly below 140 °F receiving ALU command) to performed BLU (devices receiving BLU command and devices with a temperature setpoint was 140 °F receiving an ALU command), performed ALU results on average in higher GHG emissions reduction and higher grid benefits (Table 8).

[4] N=15, results are not significant
[5] N=6, results are not significant

Table 8. Load shifting results by observed behavior

	Performed ALU	Performed BLU
Energy Shifted to Load Up phase (2pm – 4pm, daily)	+ 0.45 kWh	+ 0.03 kWh
Energy Shifted out of Peak (4pm – 9pm, daily)	- 0.40 kWh	- 0.29 kWh
Energy Usage Impact	+ 1%	+ 0%
GHG Impact	- 4%	+ 0%
Grid Impact (annual)	- $25	- $15

Impact of Load Up Parameters

ALU parameters, including duration, setpoint change and efficiency mode also impact results. Across the different parameter combinations implemented, we found that we could reduce the amount of energy pre-loaded into the HPWH without degrading curtailment results (Table 9). Comparing 2023-24 that used a fixed temperature setpoint (140 °F) change during load up to 2025 that used a relative setpoint change during Load Up, less energy was used overall and during load up in 2025, but energy reduced during shed was similar.

Table 9. ALU results relative to baseline based on ALU parameters

	2023	2024	2025
ALU Duration	2hrs	1hr 45min	2hrs
ALU Parameters	Setpoint 140 °F No change in efficiency mode	Setpoint 140 °F No change in efficiency mode	Setpoint +10 °F Heat pump mode
Energy Shifted to Load Up phase (2pm – 4pm, daily)	+ 0.71 kWh	+ 0.63 kWh	+ 0.45 kWh
Energy Shifted out of Peak (4pm – 9pm, daily)	- 0.42 kWh	- 0.45 kWh	- 0.40 kWh
Energy Impact	+ 9%	+ 1%	+ 1%
GHG Impact (annual)	+ 1%	- 6%	- 4%
Peak Power Reduction	- 0.2 kW	- 0.2 kW	- 0.2 kW

The reduction in energy use during load up comes in large part from the suppression of the RE during that phase (Figure 6). Exact disaggregation between the impact of efficiency mode control and setpoint however is not available as both changes were implemented by the DERMS provider at the same time.

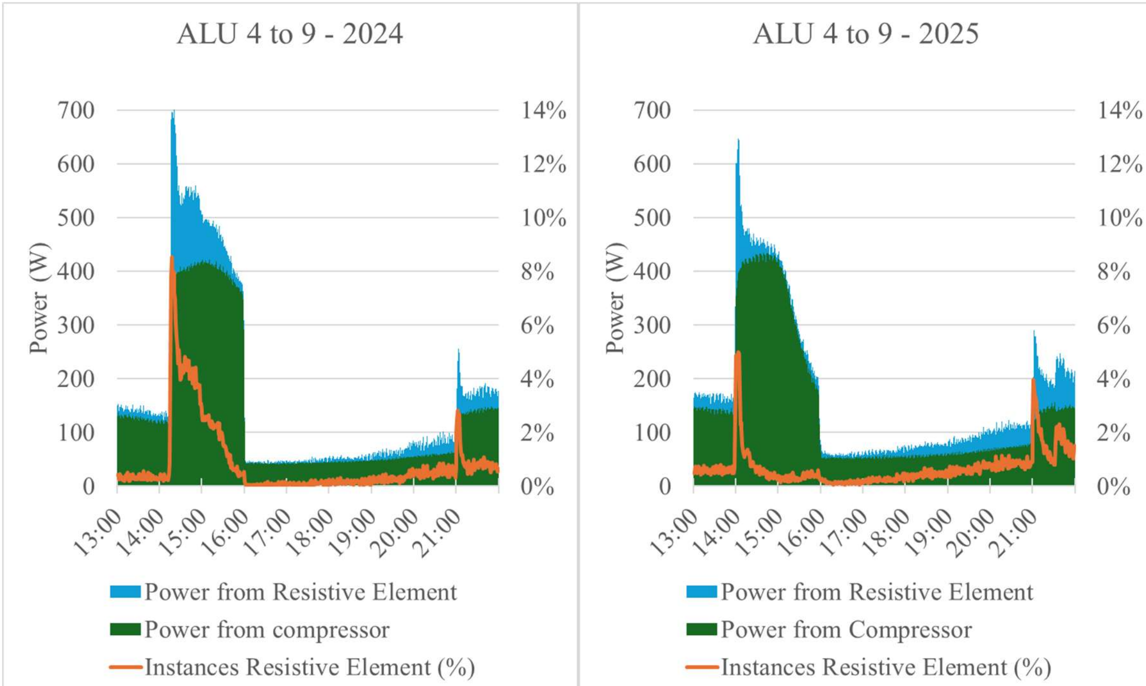

Figure 6. Share of energy usage from resistive element and compressor without (2024) and with (2025) efficiency mode control during ALU

Discussion

Operational Intersection of User Setpoints and Load Shifting

Controlled laboratory testing establishes a clear inverse relationship between a HPWH's temperature setpoint and its COP. WatterSaver's empirical data demonstrates that real-world field installations experience an even sharper efficiency penalty than predicted by laboratory models, although there may be other contributing factors, such as increased standby and distribution losses and higher domestic hot water usage. In addition to the impact on daily energy usage, the user setpoint also creates a boundary condition that dictates whether a signaled load shifting command translates into a true load shifting action or an ineffective control event:

- The low setpoint constraint (110 °F or minimum allowed tank temperature): When customers maintain a low setpoint, the thermal battery has limited to no capacity for meaningful shed. While this optimizes baseline COP, it severely restricts the HPWH's capability to safely execute a Shed command without risking user discomfort, particularly during BLU where no pre-event thermal buffering occurs.
- The high setpoint constraint (140 °F or maximum allowed tank temperature): Conversely, when a user setpoint is at the OEM's maximum allowable temperature, ALU becomes behaviorally impossible because the HPWH cannot store additional thermal energy beyond this limit. Consequently, ALU commands dispatched to those HPWHs result in

standard BLU responses, mimicking the exact shed and post-shed load shapes of the BLU cohort.

- The "sweet spot" (120 °F to 130 °F): Intermediate setpoints unlock the true programmatic variance between ALU and BLU. ALU successfully pre-charges HPWHs, enabling complete load suppression during the peak 4 p.m. to 9 p.m. window while entirely mitigating the post-shed snap-back effect. Under BLU, there is some capacity for shed, however the lack of a thermal buffer forces some HPWHs to prematurely recover mid-peak or cause a massive spike in grid demand immediately after the peak. While undesirable in response to an evening peak, this type of behavior can be acceptable in response to a morning peak, driving electric demand post-peak once renewable production sources come online. Future programs with larger customer populations will need to consider staggering recovery based on utility and grid needs.

HPWH Installation Guidance

A HPWH temperature setpoint in normal operation impacts the customer's baseline energy usage as well as the grid and societal benefits of load shifting. In order to both minimize customer's energy usage and maximize the load shifting potential of newly installed HPWHs, HPWHs should not be set at the highest setpoint allowed by the manufacturer unless absolutely necessary to meet domestic hot water needs.

While the size and the settings implemented at the time of HPWH installations are ultimately based on site constraints and customer preferences, whenever possible, the program recommendations for HPWH sizing and settings to maximize customer satisfaction, load shifting potential and grid benefits, which align with the U.S. Department of Energy Heat Pump Water Heater Installation Tool, are as follow:

- Right-sizing equipment: HPWH should be sized to meet household demand using a 120 °F to 130 °F tank temperature setpoint in heat pump only mode. This may require upsizing equipment storage volume (where space and budget permit) compared to what would be necessary to meet the Plumbing Code First Hour Rating in "hybrid" mode.
- Mandatory TMV: Installing a TMV must be standard practice. The TMV should be set to deliver safe water temperatures to the fixtures (120 °F to 125 °F), enabling utility programs to call ALU events.

Right Sizing Load Up

The program demonstrated that the energy penalty of ALU can be engineered away through control logic.

In 2023, dispatching fixed ALU temperature target of 140 °F without modifying efficiency modes caused a 9% overall increase in energy usage and a 1% increase in GHG emissions, driven heavily by the triggering of HPWHs backup resistive elements to meet the aggressive temperature target and also storing more energy than was necessary to complete a full shed. By 2025, the implementation team adjusted the strategy to a relative temperature setpoint increase (+10 °F above customer setpoint) coupled with a mandatory transition to Heat Pump Only mode.

This algorithmic refinement successfully suppressed the resistive element during the Load Up phase. As a result, the 2025 ALU strategy achieved a limited 1% increase in total energy usage and a 4% reduction in GHG emissions, all while delivering identical peak shedding performance (-0.40 kWh) and peak power reductions (-0.2 kW) as previous iterations.

WatterSaver only tested a limited number of ALU parameters combinations, without considering individual usage patterns. The program results show the importance of right sizing load up temperature increase, load up duration and controlling the efficiency mode of the HPWH to achieve an energy efficient ALU. By adding individual usage patterns (Grant et al. 2025), the implementation team anticipates that greater grid benefits and customer bill savings can be achieved.

Conclusion

The WatterSaver pilot program demonstrated that load shifting of HPWHs is a viable mechanism for mitigating California's deepening duck curve. However, the program's primary takeaway is definitive: hotter is not always better, both in user setpoint and in ALU parameters.

In analyzing the results by user setpoint, the program uncovered the importance of appropriate sizing and settings of HPWH and TMV at time of installation to ensure ALU behavior when using the ALU command. In comparing performed ALU and performed BLU, the program found that ALU results in the highest environmental, grid and customers benefits, which are all necessary for large scale adoption of HPWH load shifting.

The implementation team was able to reduce the additional energy consumption from ALU by changing the control algorithms while maintaining peak demand (Shed) reductions. Further optimization may be possible to better tailor responses to household daily water heating loads, likely in bins or groups. For example, households with minimal hot water usage during peak hours may benefit from a less aggressive load up (e.g., only a 5°F setpoint raise) while households with higher hot water consumption during peak hours may benefit from a more aggressive load up (e.g, a 20 °F setpoint raise).

Additionally, contractor and homeowner education about set points may be beneficial to minimize unnecessary energy consumption due to high setpoints. Some of those high setpoints may be driven by installers' desire to reduce callbacks due to hot water runouts, which could be better mitigated by right sizing the HPWH.

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