Electrification in Practice: All-Electric Single-family Home Retrofits in Northern California

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ABSTRACT

Building electrification presents a critical opportunity to reduce greenhouse gas emissions from buildings both in the near and long term. To scale electrification retrofits effectively, the industry must better understand real-world energy use, peak electric demand, and the practical challenges homeowners and contractors face during retrofits. PG&E's Code Readiness Subprogram is addressing these data gaps through a field study of all-electric single-family homes in California. This research investigates the benefits and challenges of building electrification retrofits and the real-world energy usage of equipment including heat pump water heaters, variable capacity heat pumps, induction ranges, heat pump clothes dryers, electric vehicle chargers, pool heaters and pumps, and photovoltaic systems.

The team identified and recruited homes through a partnership with California's Energy-Smart Homes Program and installed home energy monitors and circuit-level sensors in home electrical panels to capture whole-home and equipment-specific energy consumption. Data were collected through the program application records, a homeowner survey, and circuit-level power monitoring. This paper presents early insights from 15 homes in the initial phase of the study, including monthly and seasonal energy use, peak grid power demand trends, and details on homeowners' satisfaction and retrofit experience.

INTRODUCTION

Background

Household energy use makes up about 20% of U.S. energy-related greenhouse gas emissions (Goldstein, Gounaridis, & Newell, 2020). As state climate goals become more critical in the face of declining nationwide emissions limitations, a growing number of states are turning to building electrification as a key component in reaching emissions targets (ACEEE, 2022). Building electrification means converting building systems that use fossil fuels, particularly space heating, water heating, and cooking, to electric technologies. For California to meet its 2045 climate goals, 95% of water and space heating in residential and commercial buildings would need to be electrified (Edison International, 2023). However, the complete electrification of existing buildings faces challenges for both building owners and utilities, including long payback times, uncertainties around technology performance and reliability, space and electrical infrastructure constraints, and concerns about increased peak electric power demand.

To scale electrification retrofits effectively, the industry must better understand real-world electric appliance energy use, peak electric demand, and the practical challenges homeowners face during electrification retrofits. PG&E's Code Readiness Subprogram partnered with the California Energy-Smart Homes Program (ESHP) to address these data gaps through a field study of all-electric single-family homes across California. The ESHP is a residential program for new construction and alterations that offers incentives for residential dwelling units to adopt all-electric technologies. To participate in the ESHP, existing single-family homeowners must convert all on-site gas equipment to electric systems, with additional bonuses for high-efficient equipment. The electric technologies typically seen at participating ESHP homes include heat pumps (HP) for space conditioning and water heating, electric ovens, induction cooktops, and electric or HP clothes dryers. In addition, many homes have photovoltaic systems (PV) and electric vehicle (EV) chargers.

To gather detailed real-world energy usage data from all-electric homes, the research team (team) installed energy monitors and circuit-level sensors in ESHP participants' electrical panels. These devices collect one-minute interval data from panel mains and selected circuits to capture whole-home and equipment-specific energy consumption. In addition, the team surveyed participants to better understand their motivations for electrification and their experience with the installation process and performance of their electric equipment.

This paper shares early findings from the first phase of an ongoing research study. Data is collected for one year at each site; this paper includes data from homes that are partway or have completed the monitoring period. Therefore, the team focused analysis around monthly and seasonal comparisons. Table 1 includes the data collection start date for each home.

Research Scope and Objectives

Overall, the data collection effort aims to achieve the following specific objectives:

1. **Characterize whole-home electricity use in all-electric single-family homes,** including equipment and plug load demand profiles, peak power demand, and PV generation and on-site usage on a daily and seasonal basis.
2. Quantify annual and seasonal energy use of major electric end uses as installed in the market today.
3. **Understand the customer electrification journey**, including homeowner satisfaction and equipment performance and reliability.

METHODS

Recruitment

This research effort was conducted as a collaboration with Code Readiness and the ESHP and focused on all-electric single-family home retrofits. Recruitment criteria included ESHP participating home data; site characteristics, installed technologies, location, and available electrical panel photos; to identify a diverse set of candidate homes across cities and climate zones.

Beginning in 2025 the ESHP sent outreach emails to homeowners on a rolling basis, starting with homes in Northern California, with the goal of expanding to homes in Southern California in 2026. The team followed up with homeowners that responded positively and scheduled online meetings to gather additional site information and buy-in from the participant. Where electrical panel photos were not available, the team requested them from the homeowners to confirm compatibility with the monitoring equipment, including sufficient space for the energy monitor and current transducers (CTs).

Of the 37 homeowners contacted, 30% declined to participate, 5% were not eligible, and 65% entered some stage of participation in the study. This study is ongoing and this paper shares results from the first 15 participating homes.

Data Collection

Field data. Certified electricians installed monitoring and verification (M&V) instrumentation at each participating home's main and sub electrical panels. Instrumentation consisted of one Emporia Vue 3 energy monitor per panel with two 200 Amp (A) main CTs on the mains and up to sixteen 50A CTs on selected branch circuits, aligning with the Vue 3 channel capacity. The monitor also connects to a circuit in the panel to power the monitor, which draws less than three Watts. The circuit connection also monitors the exact voltage calculating real power using the Amps from the CT and the Volts (V) from the monitor. Because voltage varies, gathering the precise voltage during each Amp reading improves the power calculation accuracy. The Emporia Vue 3 monitor has a +/- 2% measurement accuracy. The research team selected circuits for individual data collection via 50A CTs to include key energy consuming equipment such as the heat pump water heater (HPWH), space conditioning HP, air handling unit (AHU), cooking range, clothes dryer, EV charger, pool heaters and pumps, and PV. For 240V equipment that required two breakers, the team installed CTs on both lines of the circuits when possible; when only one line could be monitored, a multiplier of 2 was applied to estimate total equipment load. In rare cases where a monitor could not fit in a subpanel, the subpanel load was monitored through its feeder circuit in the main panel. Data were collected at one-minute intervals via an application programming interface (API) and stored in a secure database.

Participant survey. The team also conducted an in-person interview during the site visit, guided by a 12-question survey that included a mix of check boxes, ranking, and open-ended questions. The survey gathered information about the participants' experience with the retrofit and installation process, electric infrastructure upgrades, and satisfaction with their all-electric appliances. This report summarizes results from 19 survey participants, including some homeowners whose home energy data are not included in this paper due to data insufficiency.

Data Analysis

Quality assurance. After approximately one week of data collection at each home, the team confirmed that equipment energy use trends matched expectations and that PV generation was directionally correct. Additional configuration adjustments were made as needed in coordination with the monitoring platform provider. Periodic data audits and automated alerts were used throughout the monitoring period to identify monitor disconnections due to poor wi-fi connections or prolonged zero-value readings.

Energy and demand calculations. The team used the following variables and formulas to calculate whole home and equipment-level energy consumption (including PV production) in kWh for each home.

- **Home energy consumption.** The team used the below formula structure to calculate total home energy consumption (kWh) for each home.[1]

$$homeConsumption\ (kWh) = |totalGridImport^{2}| + |totalSolarProduced| - |totalGridExport|$$

[1] For sites without solar, the totalSolarProduced and totalGridExport variables were equal to zero.
[2] The positive kWh (homeConsumption) or kW (homeDemand) values from the main panel's two mains.

- **Equipment energy use.** To calculate the equipment energy consumption, the team summed the CT sensor kWh readings for each circuit.

- **Remaining loads.** The team used the following equation to determine the energy consumption of all loads that were not directly monitored, which might include other appliances, equipment, lighting, and plug loads.

$$remainingLoad = homeConsumption - mainpanelCTSum - subpanelCTSum$$

- **Grid power demand.**
  - **Average daily demand profile (15-minute resolution):** To calculate the average daily power demand for each home, the team first averaged the grid import power demand (kW) over 15-minute intervals. For each 15-minute period of the day (e.g., 00:00-00:15, 0015-00:30), the team calculated the mean power demand across all days within each home's analysis period. The result in the average 15-minute demand profile per home.
  - **Daily peak demand**: In this paper, the daily peak grid power demand is defined as the maximum 1-minute grid import power demand (kW) observed during a given day. For each home, the peak demand was identified by selecting the highest 1-minute demand value within each daily period. This metric captures the maximum instantaneous grid demand experienced on each day for each home.
  - **Top 10% of daily peak demand values**: to characterize periods of elevated grid demand, the team utilized the top 10% of daily peak demand values for each home. The team identified the 90^{th} percentile value of the daily peak demand for each home, then selected all values that fell above the 90^{th} percentile value, which represent the highest 10% of daily peak demand observations for each home.

- **Equipment power demand during grid or home peak.** To calculate the power demand contribution of each end use, the team used the minute-level timestamp from the above peak Grid or Home Peak Power Demand calculation to identify the corresponding power demand value for each monitored circuit at that timestamp. The team then categorized all circuit data to a standardized end use naming convention.

- **Seasonal summaries.** For all seasonal summaries, the team used the meteorological seasons, defined by the National Oceanic and Atmospheric Administration (NOAA) as:
  - Winter: December 1 – Feb. 28
  - Spring: March 1 – May 31
  - Summer: June 1 – August 31
  - Fall: September 1 – November 30 (NOAA, 2016)

Monthly and seasonal data adjustments. Data collection for three homes, SSF-78, SF-55, and SF-45, began midway through June. To include the summer season energy consumption for those homes, the team extrapolated the first half of the month using the average daily energy usage observed from the remaining days in June. A few homes experienced intermittent network connectivity issues, resulting in persistent zero readings for 12 or more hours per day, typically impacting a few days per month. For these error days, energy consumption was estimated using the average daily energy use for the corresponding month to maintain complete monthly datasets for comparison. Two instances where the team extrapolated 7 or 8 days of data in a month are identified within the Results section. The above adjustments were only done for monthly or seasonal energy use calculations. All error days were excluded from the power demand analyses.

SITE OVERVIEW

Table 1. Site overview

Site ID	City	CA Climate Zone (All in IECC CZ 3B or 3C)	Square Footage	Full-time Occupants	Data Start Date
B-25	Berkeley	3	891	4	07/31/25
B-53	Berkeley	3	950	2	07/31/25
D-41	Davis	12	2,136	Unknown	08/21/25
M-23	Martinez	12	1,496	4	11/15/25
MP-94	Menlo Park	3	2,200	2	05/01/25
N-42	Novato	2	1,214	3	04/28/25
P-64	Pleasanton	12	1,700	2	07/29/25
SF-45	San Francisco	3	1,800	2	06/19/25
SF-55	San Francisco	3	1,747	2	06/16/25
SF-60	San Francisco	3	1,850	2	05/21/25
SF-05	San Francisco	3	800	2	05/12/25
S-59	Sebastopol	2	1,668	4	11/18/25
SSF-78	South San Francisco	3	1,120	2	06/16/25
S-88	Sunnyvale	4	1,730	4	08/11/25
WS-07	West Sacramento	12	1,284	2	09/17/25

The following table outlines each major equipment or appliance located at the home. Please note no homes reported in this paper have battery energy storage and all the installed heat pumps (HP) are variable capacity (VC), none have backup electric resistance (ER) heating elements. Two homes have an air to water heat pump (AWHP) providing hydronic space conditioning. Most of the homes have 200A service and use a 120/240V split-phase system for a maximum rated power of 48 kW. Nine out of the 12 homes that provided relevant data either increased panel capacity, installed a new subpanel, or replaced an electric panel to accommodate the new electric equipment loads. Some equipment could not be monitored due to inaccessibility to a subpanel, lack of a dedicated circuit, or another monitoring limitation. Known equipment that could not be monitored are listed in the below table.

Table 2. Major electric equipment by site

Site ID	Individually Monitored Equipment							Known Major Equipment Not Individually Monitored
	PV	EV Charger	HVAC Equipment	Multi-Function Heat Pump [1]	Dryer: ER or HP	Heat Pump Water Heater	Range: ER or Induction (IND)	
B-25 [2]	✓	✓	HP, Ducted AHU	✓	ER	-	IND	-
B-53	-	-	Mini-split HP	-	-	-	IND	Sump pump

Site ID	Individually Monitored Equipment							Known Major Equipment Not Individually Monitored
	PV	EV Charger	HVAC Equipment	Multi-Function Heat Pump [1]	Dryer: ER or HP	Heat Pump Water Heater	Range: ER or Induction (IND)	
D-41	✓	-	HP, Ducted AHU	-	-	-	-	MFHP system, hydroponics pump, induction range, washer/dryer
M-23	✓	-	HP, Ducted AHU, Supp. Mini-split HP	-	ER	✓	ER	-
MP-94	✓	✓	Mini-split HP	-	-	✓	IND	HP pool heater, pool pump, HP dryer
N-42	✓	✓	HP, Ducted AHU	-	HP	✓	IND	-
P-64	✓	✓	HP, Ducted AHU	✓	-	-	IND	AHU, HP dryer
SF-45	✓	✓	-	✓	HP	-	IND	-
SF-55	✓	✓	AWHP, Ducted AHU	-	ER	✓	IND	Hydronic pump
SF-60	-	✓	AWHP, Ducted AHU	-	ER	✓	IND	-
SF-05	-	✓	HP, Ducted AHU	-	-	✓	IND	Dryer
S-59	✓	-	HP, Ducted AHU, Supp. Mini-split HP	✓	-	-	IND	Garage mini split, beer brewing equipment, combined HP washer/dryer
SSF-78	✓	-	-	✓	-	-	-	Induction range, ER dryer, washing machine
S-88	✓	✓	HP, Ducted AHU	✓	ER	-	IND	-
WS-07	-	-	HP, Ducted AHU	-	ER	✓	ER Oven, ER Cooktop	-

[1] Multi-function heat pump (MFHP) is a term used in this study to define two- and three- function heat pumps. However, all MFHP in this select group of sites are two-function heat pumps, or combined heat pumps, delivering hydronic space and water heating.

[2] The multi-function heat pump at B-25 serves both homes B-25 and B-53.

RESULTS

First, the team reviewed monthly home electricity consumption across the 15 monitored all-electric homes and compared it to the U.S. Energy Information Administration (EIA) data on average energy consumption among homes in California, which the team used as a benchmark for home energy consumption. The team converted monitored electricity consumption from kWh to kBtu for comparison with 2020 California statewide averages of electricity and natural gas consumption among homes (EIA, 2025). On an annual basis, the monitored homes used 26% more electricity on average than the benchmark households. When accounting for natural gas consumption, the monitored homes' average annual energy use was lower by about 28,400 Btus, or 51% of the total statewide average. The results are shown in Table 3.

Looking at total energy consumption, the monitored all-electric homes consumed substantially less energy than the benchmark households in every month on a kBtu basis. However, when comparing the electricity consumption of the monitored homes to only the electricity consumption of the benchmark households, the difference varied widely by month.

During December and January, the monitored homes consumed more than twice the electricity of the benchmark households, likely due to greater water and space heating needs that were met by natural gas in the benchmark households but by electricity at the monitored homes. However, the monitored homes consumed less electricity than the California home benchmark from July through October—likely reflecting milder summer temperatures, and therefore cooling demand, in Northern California where the homes are located.

Table 3. Average energy consumption across monitored homes and CA households

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monitored Home Electricity (kBtu)	3,458	2,721	2,347	1,924	1,958	2,050	1,972	1,721	1,695	1,838	2,328	3,654
CA Household Electricity (kBtu)	1,600	1,400	1,500	1,500	1,700	1,900	2,300	2,600	2,200	1,900	1,600	1,700
CA Household Nat. Gas (kBtu)	5,100	3,900	4,100	2,900	1,900	1,600	1,500	1,400	1,400	1,700	3,600	5,100
CA Household Elec. and Nat. Gas (kBtu)	6,700	5,300	5,600	4,400	3,600	3,500	3,800	4,000	3,600	3,600	5,200	6,800
Difference between EIA Avg. and Monitored Home Avg. (kBtu)	-3,242	-2,579	-3,253	-2,476	-1,642	-1,450	-1,828	-2,279	-1,905	-1,762	-2,872	-3,146

The team then normalized the monthly electricity consumption data on a square footage basis to allow for comparison to homes outside of this dataset. The normalized data, collected from May 2025 through May 2026, is shown in

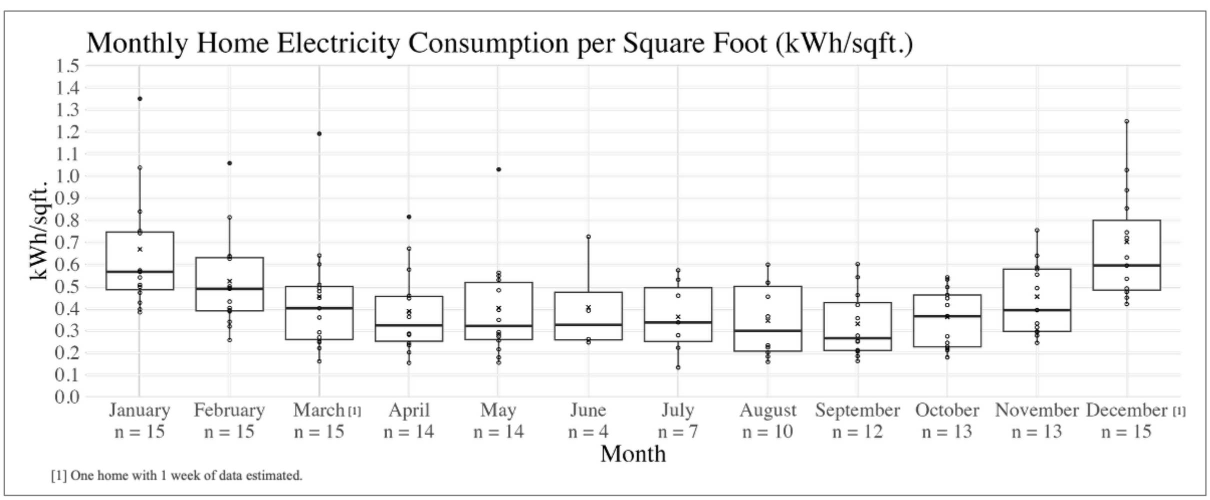

Figure 1. This boxplot identifies the median (bold line) and average (x) values of the monthly electricity consumption in the middle of the box, and the first and third quartiles—the 25th and 75th percentiles—in the lower and upper areas of the box, respectively. The minimum and maximum home electricity consumption values are identified by the whisker attached to the box and outliers are plotted individually.

Energy consumption proved to be relatively stable from April through October with monthly means between 0.33 and 0.41kWh/ft^2. Average electricity consumption was notably higher and more variable during the winter months, with average consumption rising to 0.70 and 0.67kWh/ft^2 in December and January respectively. The average monthly electricity consumption across all homes was 0.47kWh/ft^2.

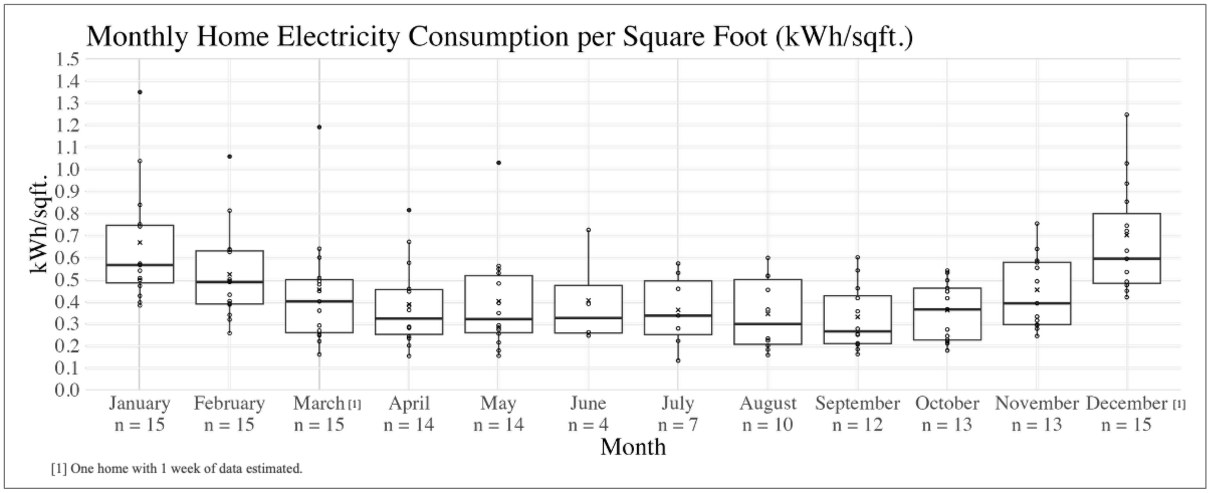

Figure 1. Monthly whole-home electricity consumption per square foot

The team then isolated homes with PV systems and analyzed whole-home electricity consumption seasonally alongside grid import, grid export, PV production, and PV consumption values, as seen in **Error! Reference source not found.** and Table 4.

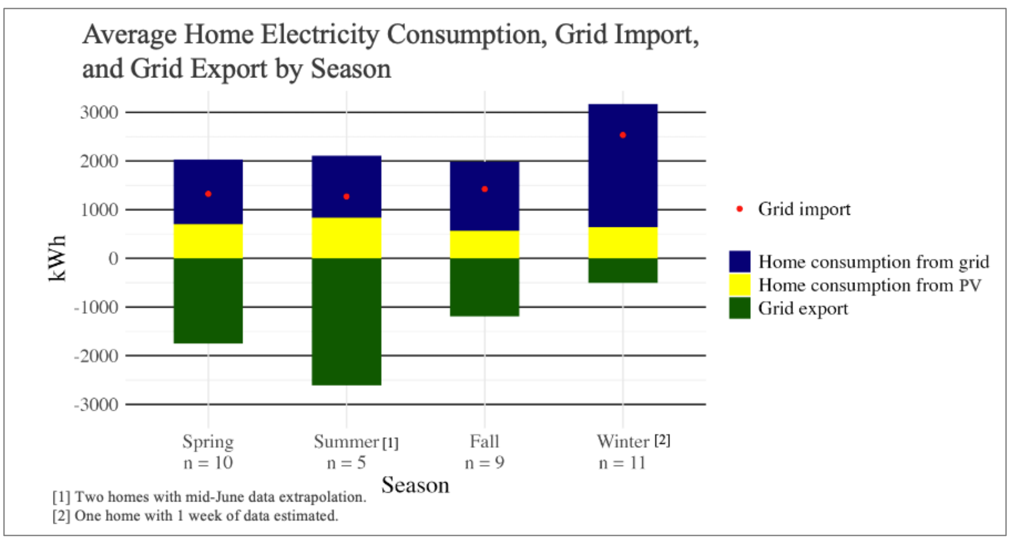

Figure 2. Home electricity consumption, grid import, and grid export by season

Whole-home electricity consumption is stable across the spring, summer, and fall at approximately 2,000kWh per season, but rises sharply in the winter to 3,172kWh – an increase of about 55%. Winter grid imports are even farther from other seasons, with average winter imports of 2,531kWh almost 90% higher than the 1,270-1,422kWh range across the spring, summer, and fall. While reduced PV production during the winter contributes to this divergence, the timing of electricity consumption and PV production is also less aligned in the winter. PV generation only contributes 20% of home electricity consumption in the winter, compared to 28% in the fall, 35% in the spring, and 40% in summer. Even if all onsite PV generation was used at the home, it would deliver only 36% of the average winter demand, indicating that load shifting alone would have a small impact. In contrast, PV generation during the spring and summer exceed home electricity consumption. However, onsite generation and consumption are significantly misaligned, and more than 70% of the generated energy is exported to the grid. These high PV exports combined with significant grid import present strong opportunities for targeted load shifting or storage deployment to significantly increase on-site PV utilization during the spring and summer.

Table 4. PV energy consumption and export by season, among homes with PV

	Summer (n=5)	Fall (n=9)	Winter (n=11)	Spring (n=10)
Average PV Energy Used Onsite (kWh)	836	562	640	705
Average PV Energy as a Percentage of Electricity Consumption	40%	28%	20%	35%
Average Percentage of Generated PV Energy Used Onsite	24%	32%	56%	29%
Average Percentage of Generated PV Energy Exported to Grid	76%	68%	44%	71%

End Use Energy Consumption

Seasonal end-use electricity consumption is shown in Figure 3. Homes with MFHP equipment, providing water heating and hydronic space heating, are separated in the chart from homes with a HPWH providing domestic hot water (DHW) and separate HVAC equipment (primarily split ducted HPs). Because monitoring start dates varied across homes, the number of monitored homes differed by season. These results should therefore be interpreted as descriptive trends rather than direct statistical comparisons. The team observed the following end use energy breakdown:

- Across all homes: Non-monitored equipment and plug loads represented a sizable portion of home seasonal energy use – ranging from 33-45% on average across all seasons.
- EV charging also represent a sizable portion of the energy use. For homes using EV charger(s), charging represented 19-33% of total energy across all seasons.
- Water heating (only homes with a dedicated HPWH), cooking, and clothes drying did not represent a substantial portion of total energy use at homes: water heating 7-9%, cooking 3-4%, and clothes drying 2-5% across seasons.
- Among homes with separate HVAC and DHW systems: though there are fewer homes with summer data, there was a notable increase in HVAC energy usage in the winter. HVAC made up 22-25% of seasonal energy use from spring through the fall and rises to 39% in the winter.
- Among homes with MFHPs: HVAC and water heating energy use represented 24-32% of seasonal energy use from spring through the fall and rises to 48% in the winter. Four of six MFHP homes included in this chart have a supplemental heat pump which also provides air conditioning, which is captured in the HVAC category, while two homes do not have cooling.

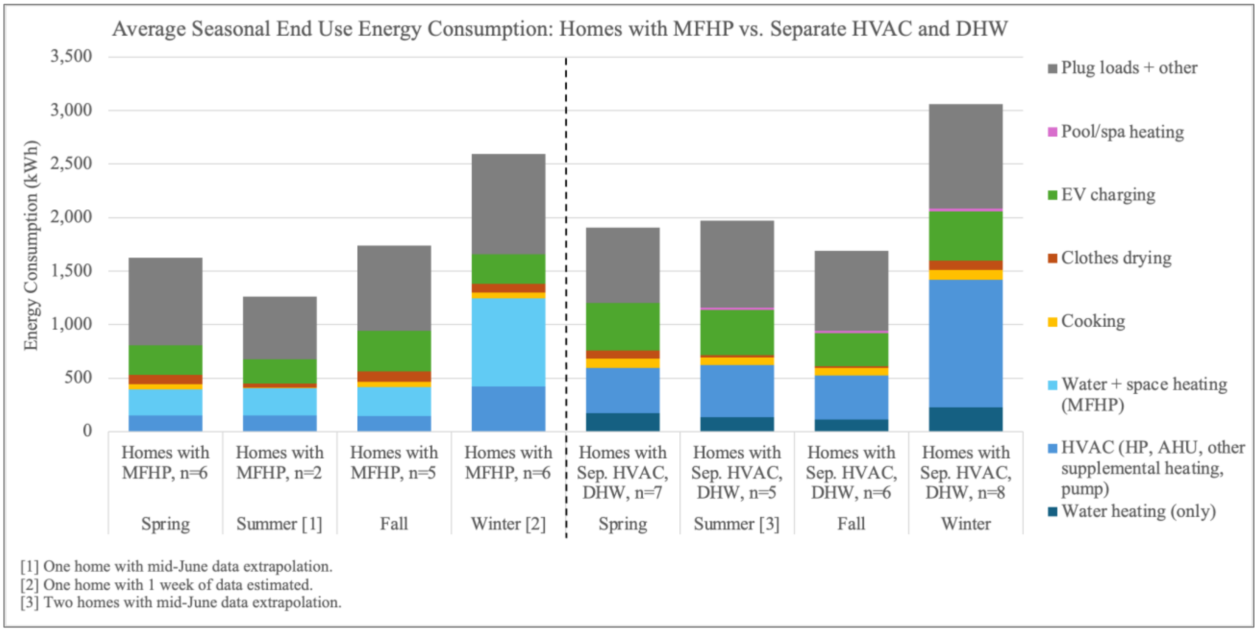

Figure 3. Average seasonal end use energy consumption

Despite the small sample sizes and differing dataset sizes, the results indicate that HVAC and DHW energy use represent a comparable percentage of total household energy consumption for homes with separate HVAC and DHW systems and those equipped with MFHPs. However, the actual energy use per home with MFHP systems is lower, as shown in Table 5. Further data collection from homes with MFHPs and further analysis into the HVAC and DHW energy use and run time among all-electric homes will be a key part of the next phase of this research effort.

Table 5. HVAC and DHW average seasonal energy use by HVAC and DHW system configuration

	Average Seasonal HVAC and DHW Energy Use per Home (kWh)		Average Seasonal HVAC and DHW Energy Use (% of Total Seasonal Energy Use)	
	Homes with MFHP	Homes with Separate HVAC and DHW	Homes with MFHP	Homes with Separate HVAC and DHW
Spring	398	598	24%	31%
Summer	408	623	32%	32%
Fall	416	527	24%	31%
Winter	1,244	1,417	48%	46%

Average and Peak Grid Power Demand

To identify the average grid power demand profile for each home, the team calculated the mean power demand in 15-minute intervals across all days. The team plotted each home's average grid demand profile and the cumulative, or aggregated, average energy use across all homes to visualize the collective typical grid demand of the 15 monitored all-electric homes across a day (Figure 4). Across all monitored homes, the mean 15-minute power demand ranged from 0.06-4.1kW. Most of the distinct demand increases are due to equipment operating on a schedule, such as pool pumps, HVAC HPs, and EV chargers.

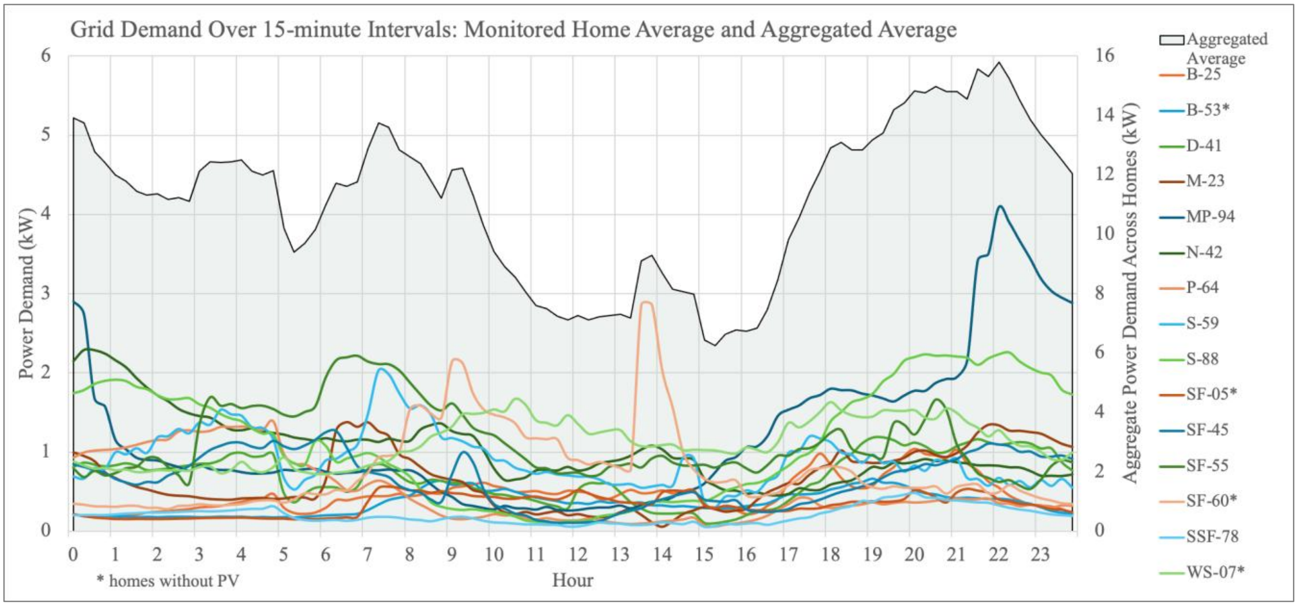

Figure 4. Grid demand over 15-minute intervals

To better understand the home's peak grid demand, the team identified the maximum 1-minute daily grid power demand, or daily peak demand, for each day the home was monitored. Each daily peak was then plotted into Figure 5, a boxplot highlighting the spread or variability of the daily 1-minute peak demand values. In this plot, the mean is identified with an x, the maximum value is labeled, and homes are ordered by mean value, highest to lowest.

A 100A panel has a limit of 24kW (the dotted orange line in Figure 5), and a 200A panel has a limit of 48kW. Fourteen of 15 homes had a maximum 1-minute grid demand of less than 23kW and 12 homes had a maximum less than 16kW. Most homes had a 200A panel but experienced peaks far lower than their rated limit. The mean daily peak demand ranged from 2.72-6.52kW, with the median ranging from 2.17-6.55kW, further highlighting that these monitored all-electric homes typically have peaks well below the 100A panel limit of 24kW.

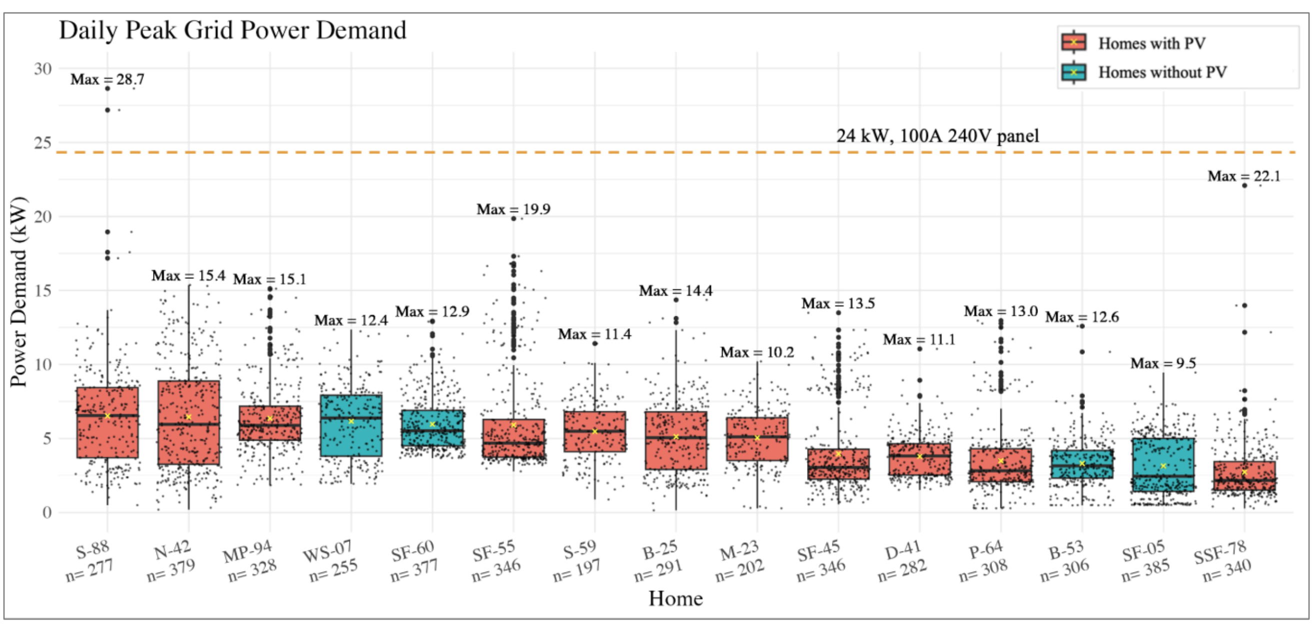

Figure 5. Daily 1-minute grid peak demand

Next, the team examined when the daily peak grid demand occurs, and whether it coincides with the typical time-of-use (TOU) peak pricing and grid stress periods of 4-9pm. The team focused on the highest daily peak values, selecting the top 10% of 1-minute peak grid demand (kW) values per home ("peak demand events"). Figure 6 shows the peak demand events for all homes, grouped by homes with and without PV.

Across the homes, 34% of the peak demand events occurred during 4-9pm, which is shaded in yellow in Figure 4. These hours also contain the highest three peak demand events, ranging from 22-28kW. Elevated peak demand instances continued between 9-11pm, comprising another 11% of the total peak demand events occurred.

The peak demand events also clustered between 7 and 10am, which contained another 19% of the events across all homes. However, this morning peak is more pronounced for homes without PV, which saw 27% of the total peak demand events during 7-10am, but only 16% for homes with PV. This difference likely reflects the contribution of morning PV generation, which offsets elevated morning demand for homes with PV throughout most of the year.

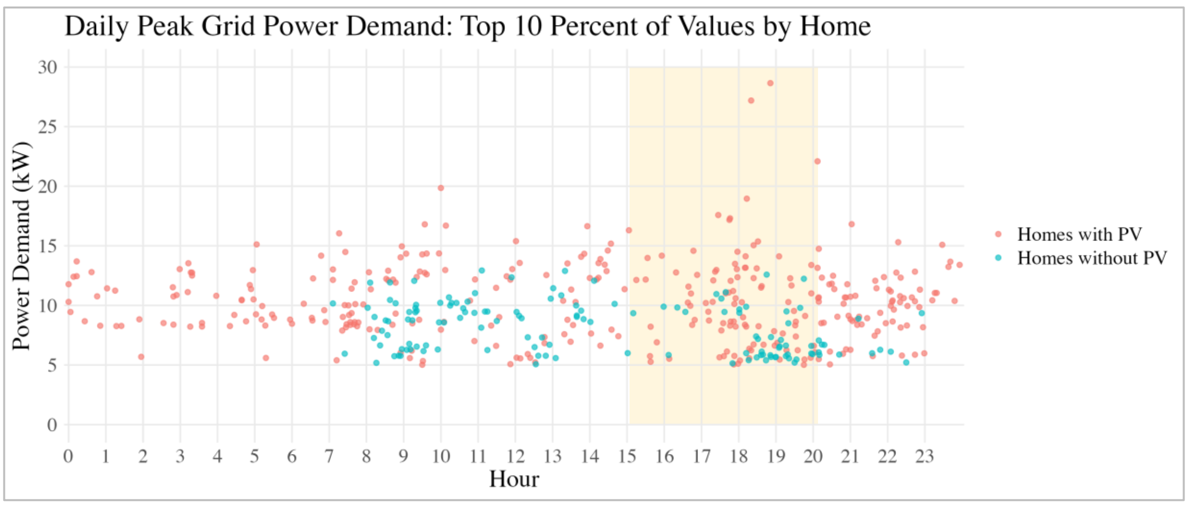

Figure 6. Daily grid power demand: top 10% of values per home

End Use Contribution to Peak Grid Demand

After identifying peak power demand trends, a natural next question is: which end uses drove those peaks? To answer this, the team analyzed the contribution of each end use towards peak demand events (the top 10% of 1-minute peak grid demand values per home). Results are summarized in Table 6, which includes the average contribution of each end use in kW for each home and the average percentage contribution of the end use across all homes.

Across all homes, the largest end use contributors during peak demand events were EV charging, plug loads, and clothes drying. Dryer heating source emerged as an important differentiator: at homes with electric resistance dryers, clothes drying contributed an average of 3.3kW during peak demand events, while heat pump dryers—which have substantially lower maximum power draws—contributed 0.1kW or less.

Among 14 homes with dedicated HVAC systems, the HVAC load was present during times of peak demand at every home but only accounted for 15% of the total demand on average and only exceeded 2.5kW at two homes. Contributions from HPWHs were even lower, averaging 8% of total peak demand across homes and less than 1kW. Combined HVAC and DHW system demand at homes with MFHP systems was only slightly lower during peak demand events than combined demand at homes with separate HVAC and DHW systems: on average, MFHP systems contributed 1.7kW or 19%, to total demand, while separate systems contributed 2kW, or 21%, to total demand.

Cooking loads during peak grid demand events was more variable across homes. While cooking was not a major contributor at most sites, it dominated peak grid demand at two homes, with average contributions of 4.2 and 3.9kW. One of these homes had an induction cooktop and one had an ER cooktop, but both had electric ovens.

Table 6. End use average contribution to top 10% of daily peak demand (kW)[3]

	Water heating (HPWH only) (kW)	HVAC (HP, AHU, other) (kW)	Water + space heating (HP only) (kW)	Cooking (kW)	Clothes drying (kW)	EV charging (kW)	Pool/spa heating (kW)	Plug loads + other (kW)
B-25		1.3	0.2	1.2	4.6	1.2		2.7
B-53*		0.7		4.2				1.2
M-23	0.4	0.7		0.8	4.7			1.1
MP-94	2.5	1.5		0.1		0.3	0.8	6.5
N-42	0.2	0.9		0.1	0.0	9.9		0.9
P-64		0.7	0.6	0.8		1.3		1.5
SF-45		0.2	1.0	0.0	0.1	6.3		1.0
SF-55	0.1	2.6		0.6	1.2	6.6		1.1
SF-60*	0.3	3.1		2.1	3.0	0.0		1.0
SF-05*	0.8	0.6		3.9				
S-59		2.3	0.9	1.9				2.6
SSF-78		0.4	1.0					14.1
S-88		0.6	0.8	1.0	2.1	4.7		4.0
WS-07*	0.7	1.2		2.9	4.0			1.5
Avg[4].	0.7	1.2	0.8	1.5	2.5	3.8	0.8	3.0
Avg. Percent[5]	8%	13%	8%	21%	25%	36%	7%	27%

*Homes without PV

Survey Results

Nineteen participating homeowners or primary occupants completed the survey. At the time of survey completion, most respondents had lived in a fully electrified home for between six and 12 months. Because respondents were recruited through an electrification incentive program, the results represent a non-representative sample of early adopters. Survey questions covered retrofit motivations, drivers of equipment choice, installation experience, and satisfaction with all-electric equipment.

To qualify for the all-electric home rebate program, most respondents replaced some functioning gas equipment, with about 80% of replaced appliances still operational. Electrification was primarily motivated by environmental goals and available rebates or incentives, although some participants also cited financial considerations, preference for

[3] Table cell fill color indicates the highest values in green and is applied separately for each site.
[4] Average among sites with monitored data from each end use.
[5] Average of the individual percentage contributions across sites; represents proportional contributions.

induction cooking, or better utilization of their existing PV system. All respondents researched equipment options themselves, often purchasing smaller appliances such as ranges or dryers directly while relying on contractors to select and install larger systems such as HPs. The most important decision factors were energy efficiency and performance, followed by price and installer recommendation.

Nearly all respondents reported at least one challenge or pain point with their home's electrification. The challenges varied across technical, financial, personal experience, and time-based difficulties. The most common challenge was project overall cost, with 35% of respondents agreeing that electrification was more expensive than they had anticipated when planning for equipment replacement. Twenty-nine percent of respondents faced utility-related delays or faced a learning curve with new equipment controls and applications-particularly when a preexisting smart thermostat was replaced by the new HP manufacturer version. Other common challenges included identifying knowledgeable contractors and navigating technical and financial decision-making, and when homeowners perceived that contractors were unfamiliar with technology, were unable to give recommendations, or made mistakes during installation, their overall experience was negatively impacted.

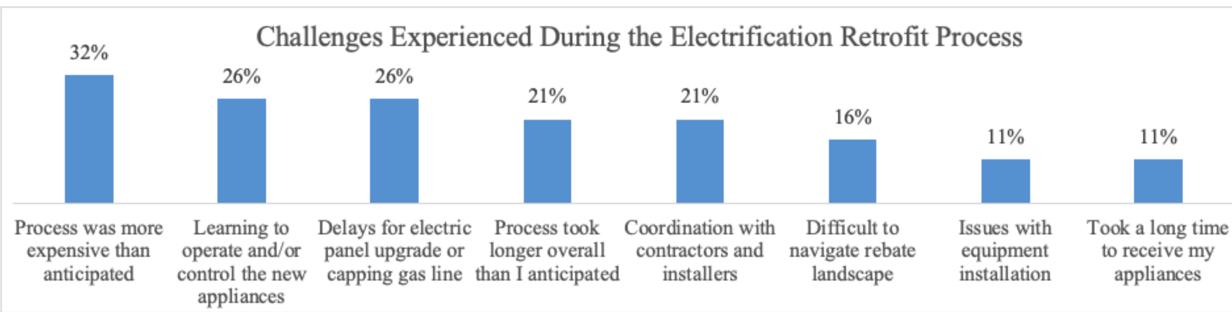

Figure 7. Challenges experienced during the electrification retrofit process. Multi-select, n=19.

Eighty percent or more of homeowners were satisfied with the performance of all their major electric equipment. Satisfaction was especially high for dryers and HPWHs (100% satisfaction). In general, satisfaction with HP installation and performance was higher than satisfaction with HP options and cost. Homeowners with MFHPs reported similar satisfaction levels with their heating system installation and performance as homeowners with separate HVAC and DHW systems, but homeowners with MFHP were less satisfied with the equipment options and cost. For each major equipment type—HVAC, DHW, cooking, and clothes drying—more than half of respondents rated their new equipment's performance as "slightly better" or "much better" than the performance of the equipment that was replaced, and about one third of respondents rated the performance equivalently. Out of each equipment type, respondents generally rated the performance of their new electric DHW system highest when compared to replaced equipment performance. Respondents were about twice as likely to report decreased performance from gas equipment with electric HVAC systems and stovetops or ranges than water heaters or dryers.

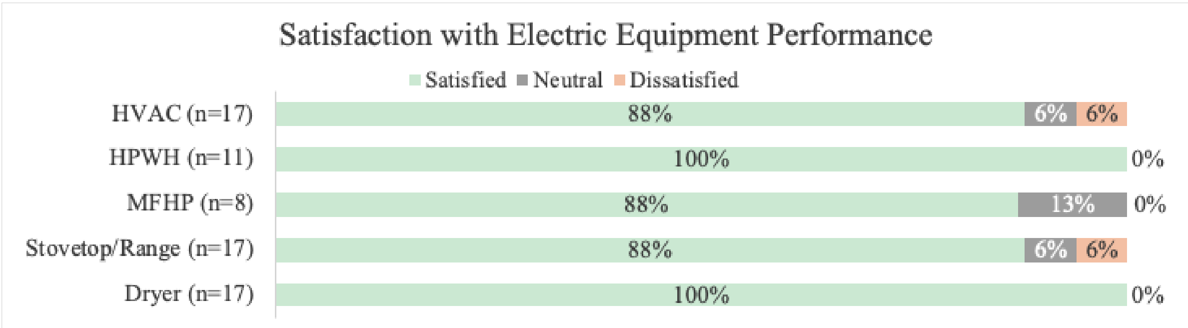

Figure 8. Satisfaction with electric equipment performance

Forty-seven percent of respondents experienced issues with their new electric equipment in the first few years of operation, ranging across problems with installation, technology, and software. While the equipment installers typically covered the full cost of issue resolution, these issues affected homeowners' overall perception of their electrification experience.

DISCUSSION AND KEY FINDINGS

Characterize Whole-Home and End Use Electricity Consumption

On an annual basis, the 15 all-electric single-family homes used 26% more electricity on average than the 2020 EIA California household benchmark. Accounting for natural gas consumption, the monitored homes' average annual energy use was 51% lower than the total statewide benchmark average.

Across this sample of homes, monthly electricity use averaged roughly 0.35-0.7kWh/ft²-month, with markedly higher usage in the winter. Winter increases were driven primarily by HVAC, which accounted for 39% of average total winter energy use across homes with dedicated HVAC systems. This distribution of energy use was wider than expected from a sample consisting entirely of early all-electric adopters in Northern California, with some homes using substantially more energy than others on both a total and floor-area-normalized basis.

At homes with PV, on-site generation met about 20% of total electricity use in the winter, but only 40% in summer. Despite PV generation in excess of total home consumption during the spring and summer, most PV generation was exported rather than used on site, suggesting substantial opportunities for load shifting or battery storage to utilize more PV on-site, reduce reliance on the grid, and potentially reduce demand during the 4-9pm TOU peak pricing period. While the opportunity is lower in the winter because most PV energy is already used onsite, there is still room for batteries to enable homes to take further advantage of their total PV on-site production and reduce electricity consumption from the grid.

Across all homes, non-monitored equipment and plug loads made up a large portion of electricity use in every season. Space conditioning was the largest single end use in terms of electricity consumption (22-39%), followed by EV charging (19-33%). Water heating, cooking, and clothes drying all represented less than 10% of electricity use on average across seasons. In this preliminary analysis, MFHP systems used less energy than separate HVAC and DHW systems on a seasonal basis, though both represented a comparable percentage of average total household energy use. Further data collection and analysis is needed to compare MFHP equipment operation and efficiency to separate HP HVAC and HPWH equipment.

Quantify and Categorize Peak Grid Demand

Across the entire data monitoring period, all homes had a maximum 1-minute grid demand of less than 30kw, and 14 of 15 homes had a maximum 1-minute grid demand of less than 23kW, which is below the limit for a 100A panel. Panel rightsizing and upsizing is not a focus of this research study, but the research team hopes to share these data with other research teams to better evaluate ways to mitigate panel upgrades at single family homes that electrify their end uses.

Across all homes, 34% of the peak grid demand events occur during 4-9pm. These hours also contain the highest three peak demand events, ranging from 22-28kW, though most daily peak events fell below 15kW. The research team plans to evaluate the effectiveness of home batteries and MFHP equipment scheduling to mitigate high power demand during the grid TOU peak pricing period.

EV charging was a major contributor to peak demand, contributing 36% of the top decile of daily one-minute peak grid demand across homes with EV chargers on average. Overall, as a high driver of daily peak demand, and with time flexibility and discrete operation, EV charging stands out as a top candidate for demand response strategies. Managed EV charging programs could play a pivotal role in mitigating residential peak grid demand to reduce grid stress.

Understand the Customer Electrification Journey

Survey results indicate generally high occupant satisfaction with electric equipment performance alongside some challenges related to electrification cost and bill impacts, contractor expertise, and delays in panel upgrades. Homeowners' experience with their home electrification was meaningfully impacted by the accuracy of their expectations regarding the costs and energy bill impacts of electrification and their trust in contractor or installer expertise. These results indicate that educating contractors and installers on all-electric equipment specifications, installation, and rebates could have a substantial impact on improving homeowner satisfaction with electrification retrofits.

NEXT STEPS

Future work will incorporate a full year of monitoring for each home and broaden the sample across California climate zones and equipment types to generate a more complete and well-rounded dataset. With this dataset, the research team will develop recommendations for Title 24, Part 6 code and compliance modeling enhancements. Detailed analyses—including run time, power demand, and backup ER use—of equipment such as variable-capacity HPs, HPWHs, induction cooktops, and MFHPs may inform building energy code enhancements or market transformation opportunities. In addition, the team plans to analyze cost data gathered through the ESHP to support future Title 24, Part 6 Codes and Standards Enhancement Teams in understanding the costs of electrification retrofits, including both equipment and electric infrastructure upgrade costs. Additional analysis of equipment operating schedules, energy use, and underlying plug load assumptions may further inform compliance modeling enhancements.

REFERENCES

Citations

ACEEE. (2022). *State Policies and Rules to Enable Beneficial Electrification in Buildings through Fuel Switching.* American Council for an Energy Efficient Economy.

Edison International. (2023). *Countdown to 2045.*

EIA. (2025, May). *eia.gov.* Retrieved from 2020 RECS Survey Data: www.eia.gov/consumption/residential/data/2020/index.php?view=characteristics&src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-f7

Goldstein, B., Gounaridis, D., & Newell, J. (2020). The carbon footprint of household energy use in the United States. *Proceedings of the National Academy of Sciences*.

NOAA. (2016, March 10). *Meteorological Versus Astronomical Seasons*. Retrieved 06 08, 2026, from www.ncei.noaa.gov/news/meteorological-versus-astronomical-seasons

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