Field Demonstration of Electric Clothes Dryer Controller

Final Report

ET24SWE0023

Prepared by:

Derick Baroi AESC

Akane Karasawa ASK Energy

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Acknowledgments

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The project was conducted through the CalNEXT program under the auspices of Southern California Edison and the Emerging Technologies Program. The CalNEXT program is a statewide California electrical energy efficiency emerging technology initiative that focuses on various technology priorities.

Executive Summary

This field demonstration evaluated the performance and energy savings potential of an add-on electric clothes dryer controller in residential settings. The controller, designed to terminate drying based on exhaust air temperature and humidity, was installed in ten homes across California's Climate Zone 12, including disadvantaged communities.

The study aimed to:

- Quantify energy and greenhouse gas savings from the controller
- Assess user satisfaction and operational impacts
- Identify barriers to adoption and inform future measure development

Key findings from the study include:

- **Energy savings:** Average reduction of 19.4 percent in energy per cycle
- **Cycle time reduction:** Average decrease of 15.8 percent in drying duration
- **GHG reduction:** Estimated annual reduction of 53 to 88 kg carbon dioxide equivalent (CO_2e) per electric dryer
- **Customer feedback:** 78 percent of users noticed reduced drying time. 100 percent reported satisfaction with dryness. No significant operational issues were reported.
- **Cost effectiveness:** Simple payback ranges from 4.0 to 6.6 years, depending on usage.

Critical recommendations include:

- Promote the controller through utility incentive programs, especially in disadvantaged communities
- Improve compatibility with various dryer models through algorithm refinement
- Expand field testing with enhanced instrumentation and a larger sample size

The project included direct outreach to customers and installers. Feedback confirmed ease of installation and general user satisfaction, though it highlighted the need for professional installation due to safety considerations.

This study provides foundational data for future workpaper development to include the dryer controllers in statewide energy efficiency portfolios.

Abbreviations and Acronyms

Acronym	Meaning
CEC	California Energy Commission
CEF	combined energy factor
CFR	Code of Federal Regulations
CIA	customer implementation agreement
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DAC	disadvantaged communities
DOE	Department of Energy
EE	energy efficiency
ET	emerging technology
eTRM	electronic technical reference manual
GHG	greenhouse gas
HTR	hard-to-reach
IOU	investor-owned utility
IPMVP	International Performance Measurement and Verification Protocol
kW	kilowatt
kWh	kilowatt-hour
lbs	pounds
M&V	measurement and verification
MW	megawatt

Acronym	Meaning
NEEA	Northwest Energy Efficiency Alliance
ORNL	Oak Ridge National Lab
PA	program administrator
PG&E	Pacific Gas and Electric
PNNL	Pacific Northwest National Laboratory
RMC	remaining moisture content
RMC_{bulk}	remaining moisture content bulk
RMC_i	remaining moisture content initial
RMS	root mean square
SB	Senate Bill
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
TPM	Technology Priority Map
UEC	unit energy consumption
VAC	volts alternating current
°F	degree Fahrenheit

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Introduction

California Senate Bill (SB) 100 set a goal to achieve 100 percent clean electricity and carbon neutrality for the state by 2045 (CEC 2021). By achieving this goal, the state is expected to reduce 92 percent of its greenhouse gas (GHG) emissions through decarbonizing transportation, building, and industrial sectors. The successful implementation of SB 100 will help address climate change and benefit state residents by improving public health, advancing energy equity, and supporting a clean energy economy. However, major changes are needed from both supply and demand sides of the grid to reach this clean energy goal. For instance, the supply side will require additional generation from renewable and zero-carbon resources to meet increasing demand. It is projected that an additional 183,000 megawatts (MW) of total resources will be needed by 2045 (CEC 2021). On the demand side, it is critical to manage the increasing grid demands while adopting a carbon neutrality goal. Research and innovation are needed to promote transportation electrification, building decarbonization, energy efficiency, and load flexibility.

Residential and commercial buildings account for 25 percent of GHG emissions in the state. The largest source of GHG emissions in this sector is electricity use, followed by onsite combustion. As a result, strategies like improving the efficiency of electric appliances and replacing gas-powered equipment with electric alternatives are critical for decarbonizing buildings (CEC 2021). Energy efficiency stands out as one of the most effective, lowest-cost decarbonization strategies that can be implemented in any building. In residential buildings, highly-efficient electric appliances are key to reducing GHG emissions, not only by cutting electricity consumption but also by replacing natural gas equipment as part of broader electrification efforts.

Approximately 80 percent of US residential homes have clothes dryers, and electric clothes dryers alone account for 6 percent of residential electricity consumption (Denkenberger, et al. 2011). This level of electricity use is significant, considering that clothes dryers operate intermittently, whereas appliances like refrigerators run continuously. Additionally, the efficiency of clothes dryers has remained largely unchanged for decades, due to the absence of energy-efficiency standards at both the state and federal levels. The ENERGY STAR® rating for electric clothes dryers was only recently introduced in 2014. Therefore, improving the energy efficiency of electric clothes dryers has substantial implications for decarbonizing residential homes.

Residential electric clothes dryers typically come with timed-dry and/or automatic-dry control options. Previous studies have shown that clothes dryers often run longer than necessary, even in automatic termination mode, leading to extended drying times and energy waste (TeGrotenhuis 2014). This study investigated the energy savings potential of an add-on automatic dryer controller, an emerging technology (ET) that can help eliminate the unnecessary operation of residential clothes dryers. Prior to this study, the technology was lab-tested on four different electric dryer models using the US Department of Energy's (DOE) test procedures. The lab test resulted in estimated annual energy savings ranging from 15 to 20 percent (Calwell and Houghton 2019). In this study, the project team installed electric dryer controller in ten residential homes to evaluate its ability to reduce drying time and energy consumption in real-world applications. In addition, the team conducted a customer survey to collect information on electric clothes dryer usage patterns as well as user experience and satisfaction with the technology.

Background

Residential clothes dryers are designed to tumble-dry clothes in a heated drum to remove moisture through evaporation. Because a horizontal axis of rotation is required to create the tumbling action, residential clothes dryers are typically front-loaded. Clothes dryers use electricity to power an electric motor that rotates the drum, which is contained inside a cabinet. Vanes and/or surface textures may be incorporated into the inner surface of the drum to facilitate separation of the clothing and to increase surface areas for drying. The classifications of residential clothes dryers are summarized in Table 1.

Table 1: Residential clothes dryer classifications.

Parameter	Classification
Fuel type	Gas, Electric
Size	Compact (less than 4.4 cubic feet) Standard (4.4 cubic feet or higher)
Dryer type	Vented, Ventless
Voltage	120 volts alternating current (VAC), 240 VAC
Drying termination	Manual (Timed), Automatic
Sensors	Thermistor (Temperature), Moisture contact sensor

Source: Project team

This field study was limited to vented electric clothes dryers with an operating voltage of 240 VAC and a maximum power rating of 5.76 kilowatt (kW) with any control system. Electric clothes dryers may have different drying control options. Typical options include time, temperature, clothes type, and preprogrammed settings as used by various manufacturers. However, the drying control can be broadly classified as manual (timed) and automatic.

Dryers with manual control typically have a timer with incremental time settings (e.g., 30 minutes, 1 hour). Since there is no way to tell when clothes are dry, users tend to set the timer longer than necessary, over-drying clothes and using excess energy. Dryers with an automatic-dry feature use one of the following techniques:

- Measures exhaust air temperature with a thermistor
- Measures drum temperature and moisture content of the clothes using an electric contact moisture sensor that extends into the interior of the drum
- Measures the temperature and humidity of the exhaust air using a thermistor and humidity sensor

The user can select the types of clothing, load size, desired dryness, and desired temperature, but the dryer's control algorithm terminates drying automatically based on temperature, moisture content, or humidity. Most automatic-dry clothes dryers have temperature, humidity, and moisture sensors inside the drum. The placement of the temperature, moisture, and humidity sensors impacts the efficiency of the dryer.

Pacific Northwest National Laboratory (PNNL) conducted lab testing of a new algorithm aimed at reducing over-drying after discovering that more than 20 percent of the total energy was consumed after the clothes were already dry. This finding highlighted the potential for improving dryer efficiency through enhanced moisture detection and automatic termination algorithms (TeGrotenhuis 2014). To evaluate this hypothesis, PNNL performed additional testing by installing a low-cost humidity sensor at the exhaust of the same standard electric dryer used in the previous experiments. This sensor augmented the existing instrumentation, which included dual thermistor sensors and a contact moisture sensor positioned at the front of the drying chamber near the door. The newly developed algorithm integrated data from the added humidity sensor to improve the performance of existing termination logic. The testing showed that the new algorithm reduced the dryer runtime and achieved energy savings ranging from 7.7 to 23.6 percent (TeGrotenhuis 2014).

Incumbent Technology

The incumbent technology for this study is a manually controlled standard-size—4.4 cubic feet or greater in capacity—vented electric clothes dryer. The Code of Federal Regulations (CFR) defines a clothes dryer as "a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation" (DOE 2024). Electric clothes dryers operate entirely on electricity; the heat used to dry clothes is generated from electricity and the drum and blower are driven by electric motors. The energy efficiency of a clothes dryer is measured by combined energy factor (CEF), which has a unit of pounds per kilowatt hour (lbs/kWh). The CEF is calculated by a clothes dryer's test load weight in pounds (C) divided by total per-cycle energy consumption, which is calculated as the sum of per-cycle standby (E_{on}) and off-mode energy consumption ($E_{standby}$). A higher CEF value indicates a more efficient clothes dryer (ENERGY STAR 2014).

$$CEF = \frac{C\ (lbs)}{E_{on} + E_{standby}}$$

DOE sets energy standards and testing procedures for residential clothes dryers. The test procedures for measuring dryer energy consumption are defined in Appendices D1 and D2 of 10 CFR Part 430 Subpart B ((DOE 2024). California's 2019 Appliance Efficiency Regulation (Title 20) is aligned with the DOE standards and requires clothes dryers be tested under the Appendix D1 or D2 procedures (eTRM 2023). ENERGY STAR also mandates all qualifying dryers to undergo testing using Appendix D2 procedures (ENERGY STAR 2014).

Manufacturers must use either the Appendix D1 or D2 procedures to determine compliance with energy conservation standards for clothes dryers manufactured on or after January 1, 2015. Both test procedures use "energy test cloth," which is a pure finished bleached fabric, to load the dryer. Clothes dryers manufactured before January 1, 2015, followed test procedures in Appendix D of 10 CFR Part 430, Subpart B, which is now obsolete. A comparison of the three test procedures is presented in Table 2.

Table 2: Comparison of test methods.

Parameters	Appendix D (before January 1, 2015)	Appendix D1 (from January 1, 2015)	Appendix D2 (from January 1, 2015)
Starting moisture content	70+/-3.5%	54.0 – 61.0%	54.0 – 61.0%
Final remaining moisture content	2.5–5.0%	2.5–5.0%	<2%
Test load size – standard	7.00 ± 0.07 lb	8.45 ± 0.085 lb	8.45 ± 0.085 lb
Test load size – compact	7.00 ± 0.07 lb	3.00 ± 0.03 lb	3.00 ± 0.03 lb
Wetting water temperature	100 ±-5°F	60 ±-5°F	60 ± 5°F
Automatic termination	No	No	Yes
Correction for final remaining moisture content	Yes	Yes	No
Correction for field use	Yes	Yes	No
Dryness setting	N/A	N/A	Normal/Medium
Temperature setting	High	High	High
Cooldown mode	Not used	Not used	Included
Standby and off mode	Not included	Included in CEF	Included in CEF

Source: Code of Federal Regulations (DOE 2024)

DOE considers four product classes for vented and two product classes for ventless dryers. Table 3 shows the minimum CEF required for clothes dryers in each product class manufactured on or after January 1, 2015. California's state minimum CEF requirements for clothes dryers, set by Title 20, are the same as DOE's. To qualify as ENERGY STAR-rated, clothes dryers need to meet the higher efficiency requirements.

Table 3: Minimum CEF required for clothes dryers manufactured on or after January 1, 2015.

Product Class	DOE/Title 20 CEF (lbs/kWh)	ENERGY STAR CEF (lbs/kWh)
Vented electric standard (4.4 cubic feet or greater capacity)	3.73	3.93
Vented electric 120V compact (less than 4.4 cubic feet capacity)	3.61	3.80
Vented electric 240V compact (less than 4.4 cubic feet capacity)	3.27	3.45
Ventless electric 240V compact (less than 4.4 cubic feet capacity)	2.55	2.68
Ventless electric combination washer-dryer	2.08	Not Available

Source: (DOE 2024) (ENERGY STAR 2014)

Several studies have assessed the performance of residential clothes dryers under different testing protocols. One laboratory test compared the energy consumption of clothes dryers tested according to the procedures specified in Appendices D1 and D2 of the 10 CFR 430 Subpart B with that of dryers operated under simulated real-world conditions by varying laundry load weights, compositions, and sizes. The results showed that the dryers operating under real-world conditions consumed approximately 35 percent more energy than those operating under the standardized test procedures. The study added that the dryers operated under real-world conditions consumed more energy because they required significantly longer drying times than the durations specified in the DOE testing procedures (Denkenberger, et al. 2011).

While many existing dryers are manually controlled, an increasing number of residential clothes dryers on the market today feature automatic cycles designed to terminate drying once the desired dryness level is reached, as determined by the final remaining moisture content (RMC) in the load. The RMC is defined as the amount of moisture retained in the laundry at the end of the drying cycle. A thermistor or a contact moisture sensor located in the drum is used to monitor the RMC to determine when to end the dying cycle. However, testing of automatic termination cycles has shown that many dryers are prone to over-drying, leading to increased energy consumption. For instance, a field study conducted across 50 households in the Pacific Northwest found that using the auto-termination mode increased the electric dryer's energy use by more than 200 kWh per year. The study also found a correlation between initial moisture content and elevated energy consumption, indicating that the auto-termination function often failed to accurately estimate drying time based on RMC. This miscalculation, particularly with complex or heavy loads, resulted in over-drying and contributed to the observed increase in energy usage (Dymond, et al. 2014).

Market Share and Energy Use

Approximately 80 percent of US homes have clothes dryers. Residential clothes dryers account for six percent of residential electricity consumption and two percent of its natural gas consumption (Denkenberger, et al. 2011). In California, 69 percent of homes have clothes dryers, with energy sources split between 46 percent electric, 52 percent natural gas, and 2 percent other fuels (CEC 2019), as shown in Figure 1. Given there are a total of 13,475,623 households in California, there are over 4,312,000 electric dryers in the state (CA DOF 2020).

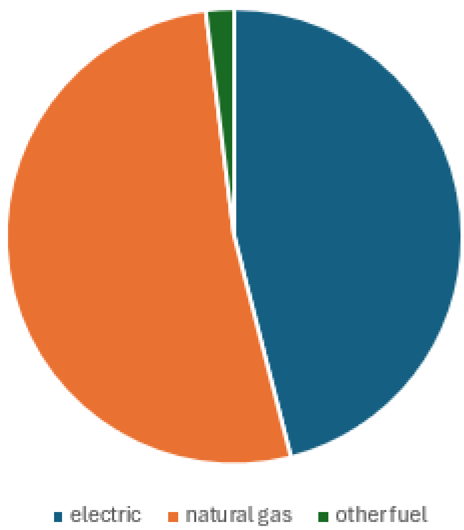


Figure 1: The energy source of clothes dryers in California.

Source: Project team, data from (CEC 2019)

The average unit energy consumption (UEC) of a residential vented standard-size electric clothes dryer is 457 kWh and that of a residential vented natural gas clothes dryer is 16 therms (eTRM 2023). The PNNL's lab test showed that adding a low-cost humidity sensor at the exhaust could result in energy savings ranging from 7.7 to 23.6 percent (TeGrotenhuis 2014). Based on the findings, the average energy savings potential of the ET could range from 38 to 118 kWh per household with an electric clothes dryer. If the ET were installed on every electric dryer in California, the potential energy savings would amount to 509 gigawatt hours. The energy savings potential would become even greater as more natural gas clothes dryers are replaced with electric clothes dryers, given the significant efforts underway to electrify residential homes.

The Emerging Technology and Product Details

The ET studied is an automatic dryer controller for electric clothes dryers. The ET consists of a duct adapter, a temperature and humidity sensor, and a controller that can be easily added onto an electric clothes dryer without tampering with existing control wiring. The temperature and humidity sensor placed in the duct adaptor monitors the temperature and humidity of the dryer exhaust air stream and turns off the dryer when the exhaust air reaches an optimal level of dryness.

The dryer controller is compatible with any residential electric dryer with an operating voltage of 240 VAC and a maximum total power load of 5.76 kW. Figure 2 shows the ET system components.

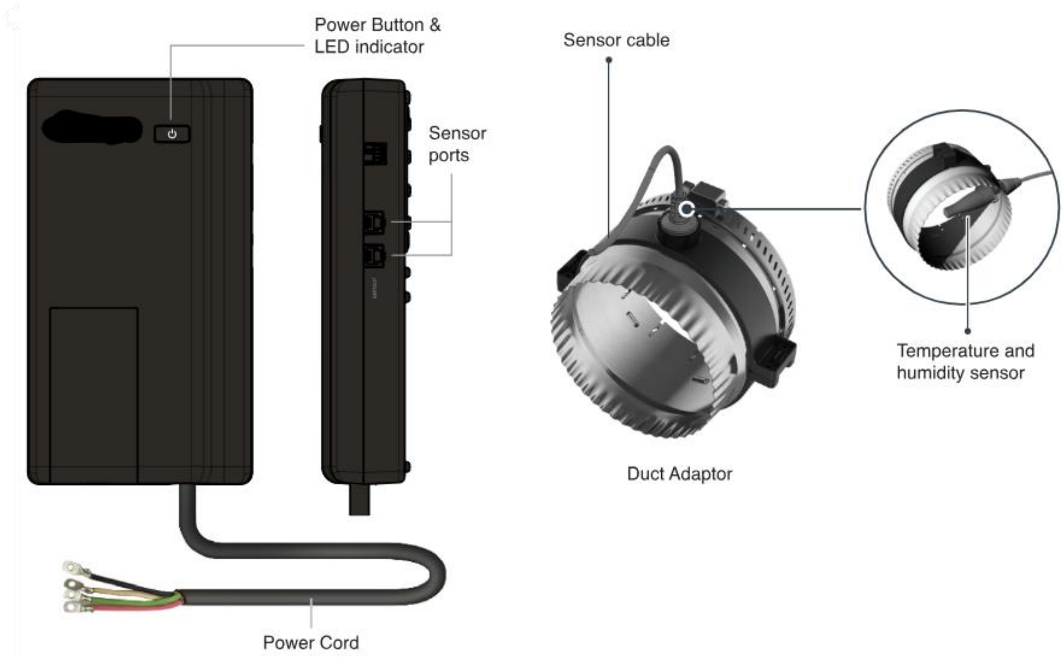


Figure 2: ET system components.

Source: ET manufacturer

The electric clothes dryer controller is added onto an existing electric dryer with no modification. Figure 3 depicts the schematic diagram of the technology installation.

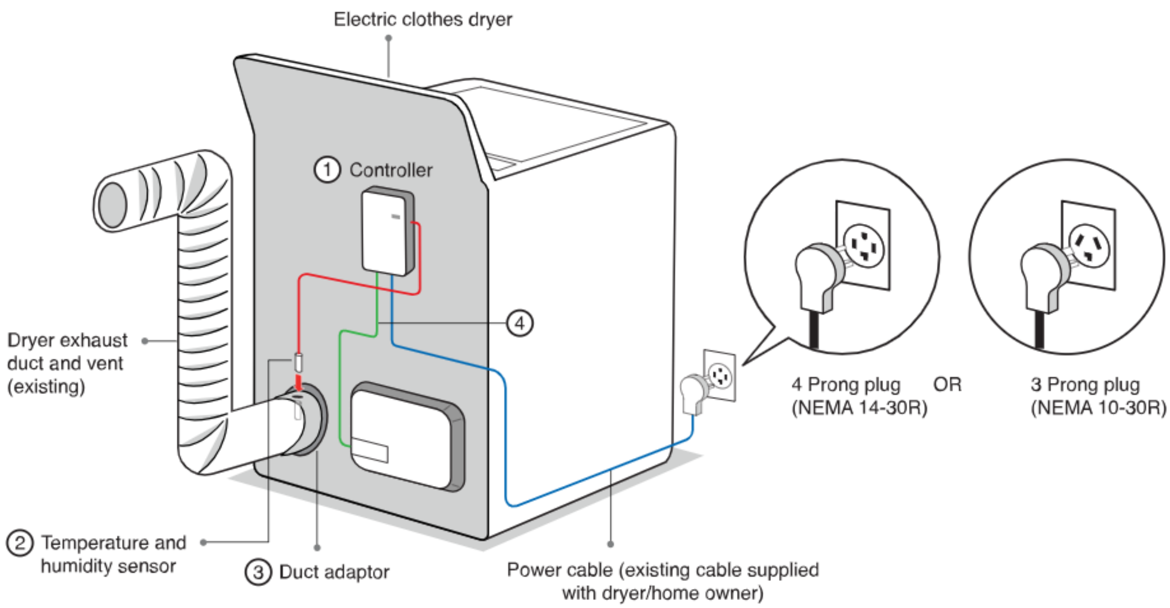


Figure 3: Schematic diagram of technology installation.

Source: ET manufacturer

Objectives

The goal of this study is to evaluate the in-field performance and the energy saving potential of the electric dryer controller in residential homes. Several objectives were established:

- Install the electric dryer controller in at least 20 residential households in California to evaluate real-world performance
- Quantify energy (kWh) and GHG savings resulting from the installation of electric dryer controllers in residential households
- Conduct a survey to gather feedback on user experience with the electric clothes dryer controller and satisfaction with clothes dryness
- Evaluate key technology barriers, opportunities, and cost-effectiveness
- Research and evaluate potential market size in California and the highest benefit applications
- Collect information necessary for future workpaper and measure development

To accomplish these objectives, we developed a testing methodology adhering to International Performance Measurement and Verification Protocol (IPMVP) principles. The methodology is outlined in the following section and was designed to directly measure performance characteristics and energy savings.

Methodology and Approach

A field study of the ET was conducted in the Pacific Gas and Electric (PG&E) territory.

Test Sites

The project team initially aimed to test the dryer controller performance in 20 residential households with existing electric dryers. The project team contacted about 30 potential participants and collected their electric dryer data. After the initial survey, the team conducted site visits at 21 customer sites between January and March 2025 to install loggers, take spot measurements, and conduct a baseline survey. A total of 19 residential households were finally selected for testing between February 5 and March 10 after a few of the potential customers dropped out. All sites were in Le Grand, California, within Climate Zone 12, and designated as SB 535 Disadvantaged Communities.

At all test sites, a 240 VAC-volt, single-phase circuit powered the vented, standard-size electric clothes dryers. The dryers were manufactured and installed between 2020 and 2022, making them three to four years old. The technical specifications of each electric clothes dryer are summarized in Table 4 below.

After three months of baseline power monitoring, the project team found that clothes dryers were not being used at eight sites. The project team contacted the site hosts and found that they were indeed not using the dryers, due to various personal reasons. One more participant opted out during the installation of the ET measure. Therefore, the final sample size was reduced to ten.

Table 4: Dryer specifications.

Site #	Make	Model	Year of Install	Electric Rating	Volume in Cubic Feet	Control Type by User
1	Maytag	MEDC465HW0	2022	120/240V 26 AMP	7.0	Timed
2	Electrolux	ELFE7337AW0	2022	120/240V 24 AMP	8.0	Timed
3	Electrolux	EFDE317TIW3	2021	120/240V 24 AMP	8.0	Timed
4	Roper	RED4516FW0	2020	120/240V 26 AMP	6.5	Timed
5	Electrolux	EFDE317TIW3	2021	120/240V 24 AMP	8.0	Timed and automatic
6	Electrolux	EFDE317TIW3	2020	120/240V 24 AMP	8.0	Timed

Site #	Make	Model	Year of Install	Electric Rating	Volume in Cubic Feet	Control Type by User
7	Electrolux	EFDE317TIW3	2020	120/240V 24 AMP	8.0	Timed and automatic
8	Electrolux	ELFE7337AW0	2022	120/240V 24 AMP	8.0	Timed
9	Whirlpool	WED5620HW2	2022	120/240V 24 AMP	7.4	Timed
10	Electrolux	ELFE7337AW0	2022	120/240V 24 AMP	8.0	Timed and automatic

Source: Project Team

Figure 4 shows the five different models of electric dryers at customer sites and their nameplates.

Figure 4: Electric dryers and their nameplate information at customer sites.

Source: Project team

Test Plan

This study employs both quantitative and qualitative analytical approaches to evaluate the performance of the electric clothes dryer controller.

Quantitative Analysis

Baseline equipment refers to an existing electric clothes dryer with the manufacturer's controller. Reporting equipment refers to an existing electric clothes dryer with the ET measure, the dryer controller, installed. The quantitative component focused on evaluating the operational benefits of reporting equipment compared to the baseline equipment. Key performance metrics include:

- **Energy savings:** The project team monitored electric energy consumption for both baseline and reporting equipment over a minimum three-month period. Data was normalized using the following techniques.
  - One-minute interval ampere data was logged.
  - Voltage and power factor were spot measured.
  - Power was calculated using Equation 1.

    Equation 1

    $$Power\ (kW) = Current\ (ampere) * Voltage\ (volt) * Power\ factor/1000$$

  - Dryer cycles typically range from 15 to 60 minutes based on the dryer manufacturer's control algorithm, with common preset durations of 15, 30, 45, or 60 minutes. The cycle length is selected by the user based on individual needs, which cannot be directly monitored. Therefore, for the purpose of this analysis, the project team defined a drying cycle as a continuous period of dryer operation. This resulted in a higher number of cycles with shorter durations per cycle. To normalize the data, a minimum dryer cycle time of 15 minutes was assumed.
  - Average power, measured in kW, was multiplied by minutes per cycle to calculate energy use per cycle (kWh per cycle), which was used as the comparison matrix across the baseline and reporting period for the specific user.
  - The average number of cycles per month per site was calculated and then used to estimate the annual energy use in kWh per site for baseline (without ET) and post-installation (with ET).
  - Annualized energy savings were estimated using Equation 2.

    Equation 2

    $$Electric\ energy\ savings\ in\ kWh = Annualized\ [Baseline\ electric\ energy\ in\ kWh - Post\ install\ electric\ energy\ in\ kWh]$$

- **Peak demand reduction:** Peak demand reduction was not calculated for this project. A reduction in average kW was calculated for each site.
- **GHG emissions reduction:** The GHG emissions reduction potential of an electric dryer was estimated from the IOU's real-time and forecasted marginal GHG emission data (SGIP 2024). Anthropogenic CO_2 emissions reduction was estimated using an average conversion factor of 0.400173 kg CO_2e per kWh for PG&E between August 2024 and July 2025.

- **Life cycle cost analysis:** Operational costs associated with the ET were evaluated, including capital expenditures, installation, energy use, and maintenance. This analysis informed a comparative life cycle cost assessment of the ET measure.
- **Nonroutine adjustments:** Nonroutine events, such as user-initiated changes in dryer operation, changes in the number of occupants per household, changes in clothing type and volume, and others, were recorded, and adjustments were made accordingly.

Qualitative Analysis

The qualitative component of this study involved investigating stakeholder perspectives through a customer survey. Customer surveys were conducted to gain insights into dryer usage habits and user experience.

Data was collected via in-person and phone interviews. An initial survey was carried out during the baseline period to understand participants' typical use of electric clothes dryers. A follow-up survey was conducted at the conclusion of the post-installation testing period to assess user experience with the installed dryer controller and satisfaction with clothes dryness. The survey responses were analyzed to identify key barriers to adoption, training needs, and to evaluate overall market readiness. Survey questions and responses are provided in Appendix C: Customer .

Customer Survey: Outcome Integration

Combined insights from both analyses informed:

- A total system benefit model
- Recommendations for measure development
- Strategies for integration into investor-owned utility (IOU) and statewide incentive programs

Measurement and Verification

The data collection was performed following IPMVP Option A: Retrofit Isolation: Key Parameter Measurement (EVO 2022). The measurement and verification (M&V) period and the key parameters are listed in Table 5.

Table 5: M&V period.

Period	Duration	Equipment	Logged Parameters	Spot Measured Parameters
Baseline	March '25–May '25	Existing electric dryer	Current	Voltage, Power factor
Reporting	June '25–August '25	Existing electric dryer with ET measure, dryer controller	Current	Voltage, Power factor

Source: Project team

The instrumentation used is listed in Table 6. The current draw of an electric clothes dryer was recorded at one-minute intervals to capture any dryer cycling that occurred. The voltage and power factor were spot measured since residential power systems operate at a fixed voltage.

Table 6: Instrumentation plan.

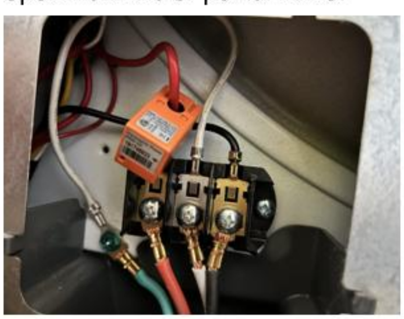
Measured Variable	Logger	Accuracy	Frequency	Period
Electric current (ampere)	PAN-10 Current Transformer	<2% at I>3A	1-minute average	Baseline and post-install
Electric voltage (volt)	EXTECH 380976 True RMS Power Clamp Meter	±1%+ 20d	Spot measurement	Baseline and post-install

Source: Project team

The project team installed nineteen PAN-10 current transformers along with cellular bridges that remotely logged the amperage at one-minute intervals. During the logger installation, voltage and power factor were spot measured using an EXTECH 380976 True RMS Power Clamp Meter. Examples of logging instrumentation installed at customer sites are shown in Figure 5.

Spot measure of power factor

Spot measure of voltage


The Wi-Fi current sensor


Cellular bridge

Figure 5: Logging instrumentations installed at a customer site.

Source: Project team

Table 7 shows the spot measured voltage and power factor of each site.

Table 7: Spot-measured data.

Site	1	2	3	4	5	6	7	8	9	10
Voltage	244.5	242.0	248.6	237.7	248.9	241.5	236.8	238.6	239.9	244.6
Power factor	0.999	0.984	0.981	0.999	0.982	0.987	0.982	0.984	0.999	0.982

Source: Project team

An electric dryer is a resistive load, and the voltage and power factor remain unchanged.

Monitoring Period

Data loggers were deployed between February 5 and March 10, 2025. Baseline energy consumption data was collected up until the installation of the electric dryer controller, which occurred between May 27 and May 28, 2025. Post-installation (reporting period) data was gathered through August 24, 2025. Table 8 summarizes the monitoring and reporting durations for each participating site.

Table 8: Monitoring period.

Site #	Logger Installed On	ET Measure Installed On	Reporting Date	Baseline Days	Reporting Days
1	2/5/2025	5/28/2025	8/24/2025	112	88
2	2/5/2025	5/27/2025	8/24/2025	111	89
3	2/5/2025	5/27/2025	8/24/2025	111	89
4	2/14/2025	5/27/2025	7/30/2025	102	64
5	2/14/2025	5/28/2025	6/29/2025	103	32
6	2/14/2025	5/27/2025	8/24/2025	102	89
7	2/25/2025	5/28/2025	8/24/2025	92	88
8	2/25/2025	5/27/2025	8/24/2025	91	89

Site #	Logger Installed On	ET Measure Installed On	Reporting Date	Baseline Days	Reporting Days
9	3/10/2025	5/27/2025	8/24/2025	78	89
10	3/10/2025	5/28/2025	8/24/2025	79	88

Source: Project team

Most sites provided approximately three months of baseline data and three months of post-installation data, supporting strong data quality and consistency. However, no dryer usage data was recorded for Site 4 during August, and for Site 5 during both July and August.

Findings

Overview

The field study was conducted across ten single-family residences, each with distinct characteristics including dryer models, household size, laundry habits, load sizes, and drying preferences. Due to this variability, data from each site were individually analyzed, normalized, and compared to ensure accurate performance assessment.

Results

The experimental results across the ten participating sites showed varied but generally positive outcomes:

- **Energy per cycle:** All sites demonstrated a reduction in energy consumption per dryer cycle, with savings ranging from 0.5 to 37 percent.
- **Cycle duration:** Nine sites experienced a decrease in drying time per cycle, ranging from 7 to 31 percent. One site showed a slight increase of 3 percent.
- **Average power:** Five sites recorded a reduction in average power draw ranging between 0.4 and 6 percent, while the remaining five showed an increase ranging between 0.1 to 7 percent.
- **GHG reduction:** The dryer controller saver has the potential to reduce 55 kg to 88 kg of CO_2e per year per dryer.
- **Customer satisfaction:** 100 percent of respondents reported satisfaction with the dryness level, indicating strong performance in core functionality. 89 percent of users noticed clothes were drier than before. 70 percent of users experienced shorter drying times, suggesting improved efficiency.

These findings suggest that while performance varies by dryer model and user behavior, the controller consistently contributes to energy savings and shorter drying cycles.

Baseline Data

Figure 6, Figure 7, Figure 8, and Figure 9 illustrate the dryer operating profiles for the ten active participants during February, March, April, and May 2025. These visualizations highlight the variability in usage patterns driven by individual household behaviors. A comprehensive summary of operating trends throughout the full baseline period of each site is provided in Appendix B: Baseline And Reporting Period Dryer Operating Profiles.

Figure 6: Screenshot of active dryers' operating trend in February 2025.

Source: Project team

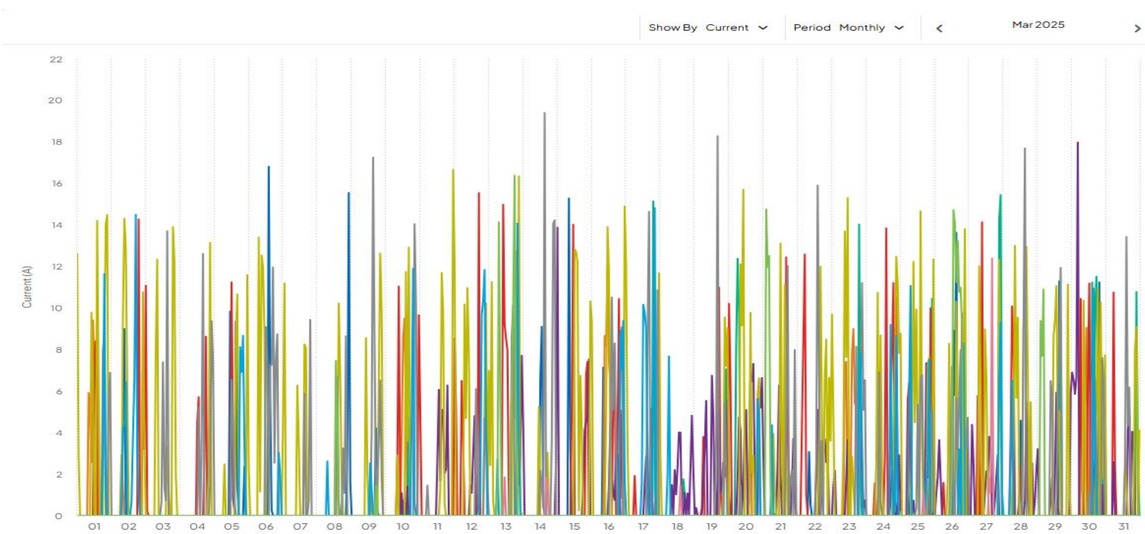


Figure 7: Screenshot of active dryers' operating trend in March 2025.

Source: Project team

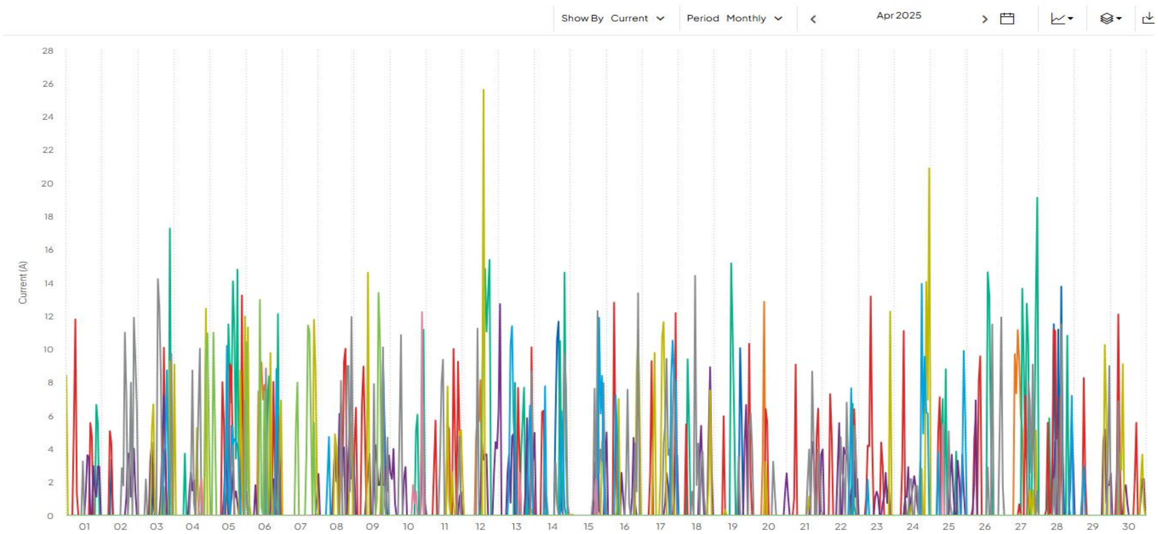


Figure 8: Screenshot of active dryers' operating trend in April 2025.

Source: Project team

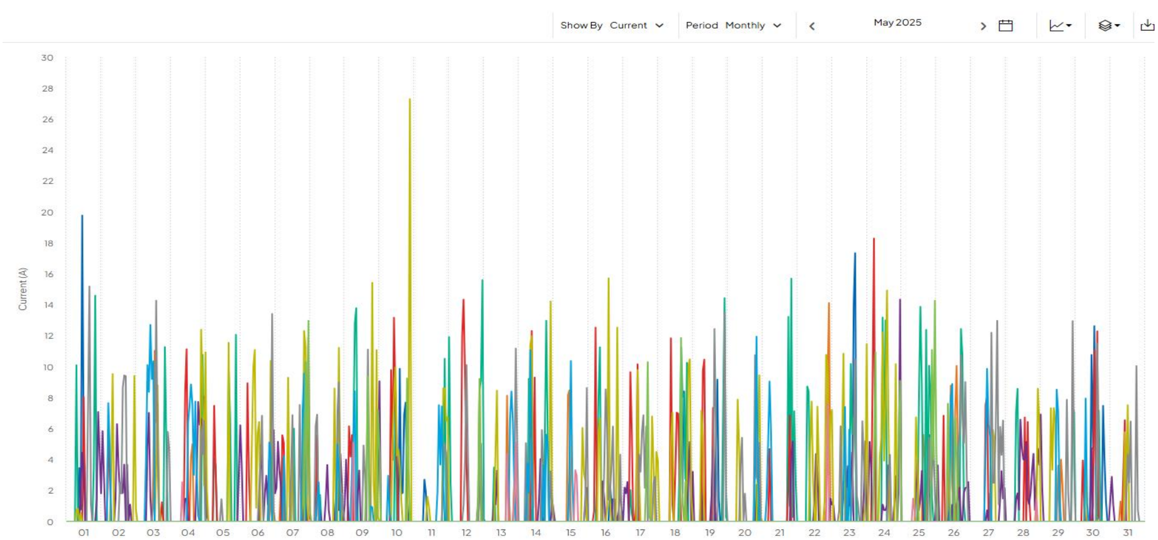


Figure 9: Screenshot of active dryers' operating trend in May 2025.

Source: Project team

Table 9 presents a summary of baseline data collected from the ten active sites. Dryer cycle length was defined as the duration of continuous operation. The average cycle time, measured in minutes per cycle, varied significantly across sites, reflecting differences in user behavior and dryer models.

Table 9: Summary of baseline period measured data.

Site #	Days	Minutes Heater ON	Minutes Dryer ON	Total kWh	Cycles	Average kW	kWh/ Cycle	Minutes/ Cycle
1	112	269	1,156	24	44	5.36	0.55	26
2	111	3,502	4,205	130	40	2.23	3.26	105
3	111	9,196	11,743	466	170	3.04	2.74	69
4	102	6,628	15,700	566	344	5.13	1.65	46
5	103	3,047	3,755	164	46	3.23	3.56	82
6	102	2,541	3,669	116	41	2.73	2.82	89
7	92	12,845	16,522	641	240	3.00	2.67	69
8	91	6,603	8,211	256	91	2.33	2.81	90
9	78	4,010	19,019	348	425	5.21	0.82	45
10	79	5,617	7,120	316	93	3.38	3.40	77

Source: Project team

Average power consumption during dryer operation ranged from 2.23 kW to 5.36 kW, consistent with user drying habits and the control algorithms of the respective dryer models. Monthly usage varied significantly among the ten households, with total operating hours ranging from as low as five hours to as high as 122 hours. 'Minutes Heater ON' represents active heating time, while 'Minutes Dryer ON' reflects the total normalized cycle duration.

Findings from Baseline Survey

During the initial site visits, the project team interviewed all 19 participants using structured questionnaires to understand their dryer usage habits. The survey revealed that most households had been using their electric dryers for over two years. Usage frequency varied, with lighter users averaging fewer than three to four loads per week, while heavier users exceeded five loads weekly. Participants commonly sorted laundry by clothing type (e.g., whites, colors, jeans), but rarely by fabric weight. Despite having access to multiple drying settings, most users relied on timed or preset cycles, with limited awareness or use of the 'Sensor Dry' feature. Drying cycles typically lasted under an hour, and overall satisfaction with dryer performance was high. Where dissatisfaction existed, it was primarily due to extended drying times. A few users also noted issues such as excessive noise or minor malfunctions. Responses from the ten active participants included in the final analysis are summarized in Table 10.

Table 10: Baseline survey results.

Question #	Questions	Responses (10 Active Sites)
1	How long have you been using this electric clothes dryer?	Not sure – 1 Less than one year – 1 One to two years – 1 Two to three years – 6 More than three years – 1
2	How many times do you use the dryer in a week?	1 load/week – 1 2–3 loads/week – 3 3–4 loads/week – 4 5–10 loads/week – 0 >10 loads/week – 0 >20 loads/week – 2
3	Do you wash clothes by type?	Separate – 7 Not separate – 1 Both – 2
4	Do you dry the same load as it is washed?	Yes – 10; no – 0
5	Which option(s) do you select to operate your dryer?	Timed dry – 5 Preset dry cycle – 3 Temperature – 2
6	How long does it usually take to dry clothes?	Not sure – 1 30 to 45 minutes – 3 1 hour – 4 1 hour and more – 2
7	Do you know and use the 'Sensor Dry' function?	Yes – 2; No – 8
8	Are you satisfied with the dryness? If not, why are you not satisfied with dryness?	Yes – 9; No – 1
9	Are there any known issues with the dryer?	Yes – 1; No – 9

Source: Project team

Measure Installation

Figure 10 shows the installed ET measures in the ten residences.

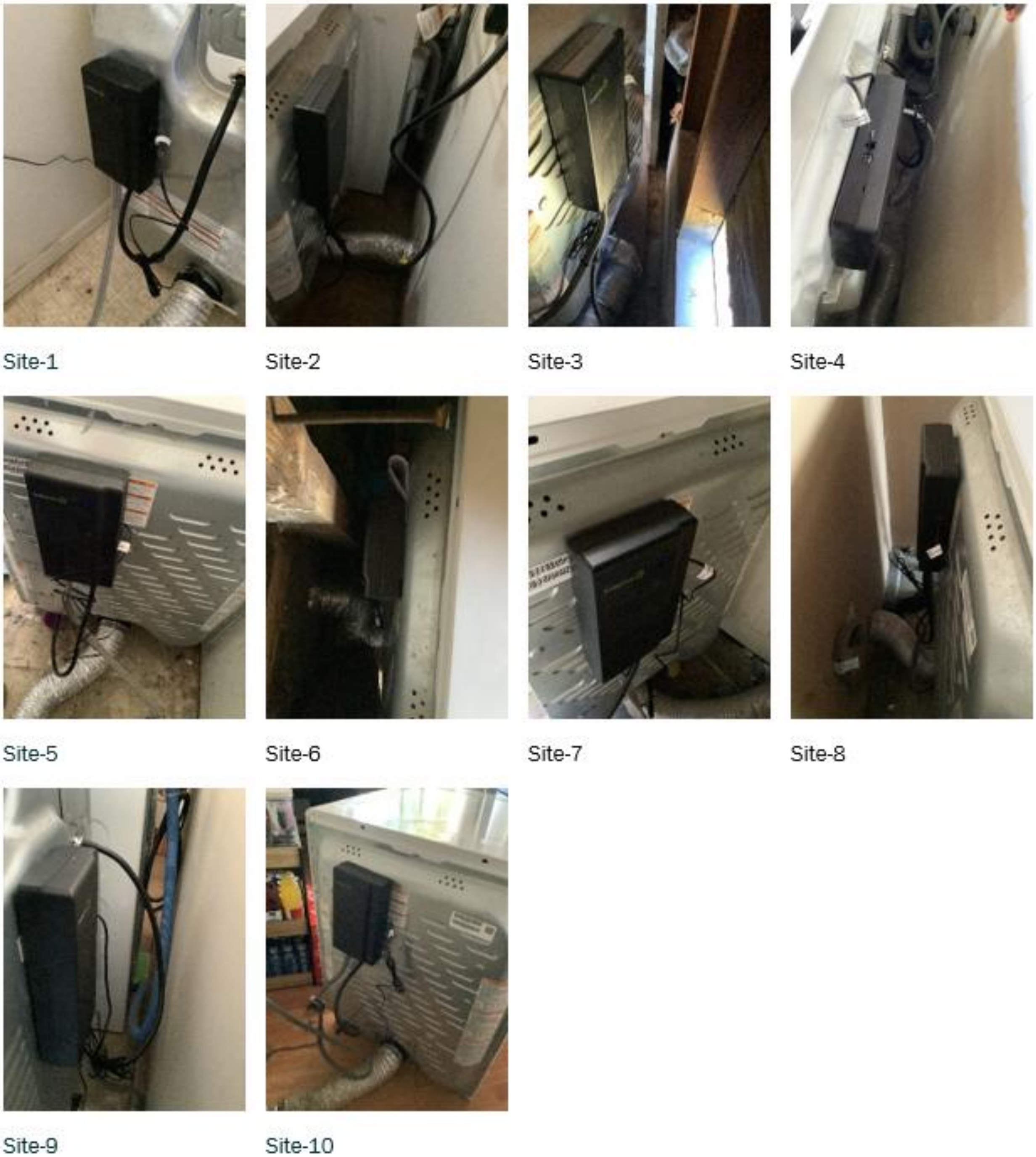


Figure 10: Installed ET measures at the ten sites.

Source: Project team

Reporting Period Data

The reporting period began on May 27, 2025, and concluded on August 24, 2025. Table 8 provides a detailed breakdown of the monitoring timeline for each site. Figure 11, Figure 12, and Figure 13 illustrate dryer operating profiles for the ten active participants during June, July, and August 2025, showcasing the variability in usage patterns driven by individual household behaviors. A complete overview of operating trends during the reporting period is available in Appendix B: Baseline And Reporting Period Dryer Operating Profiles.

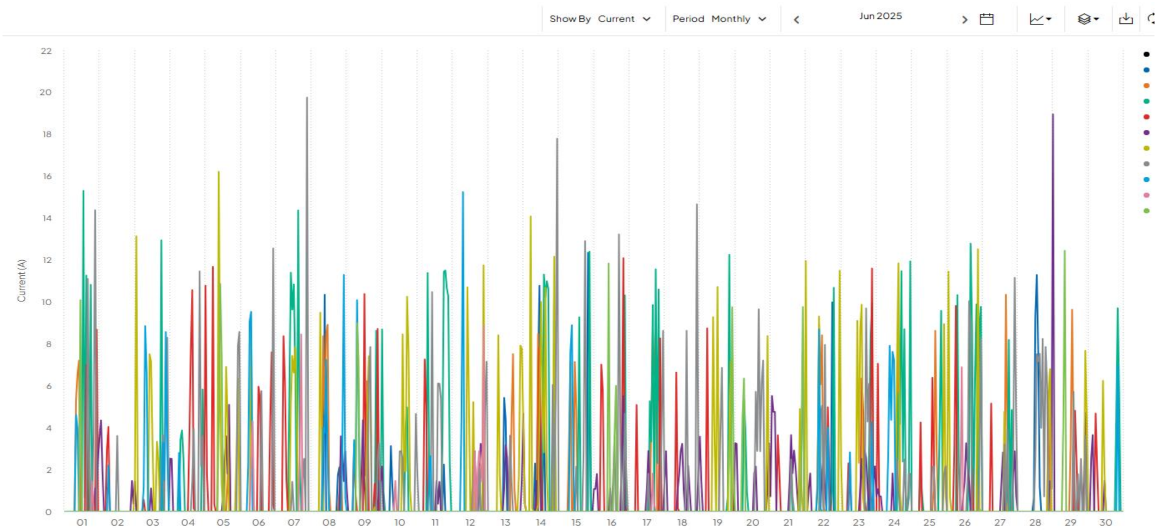


Figure 11: Screenshot of active dryers' operating trend in June 2025.

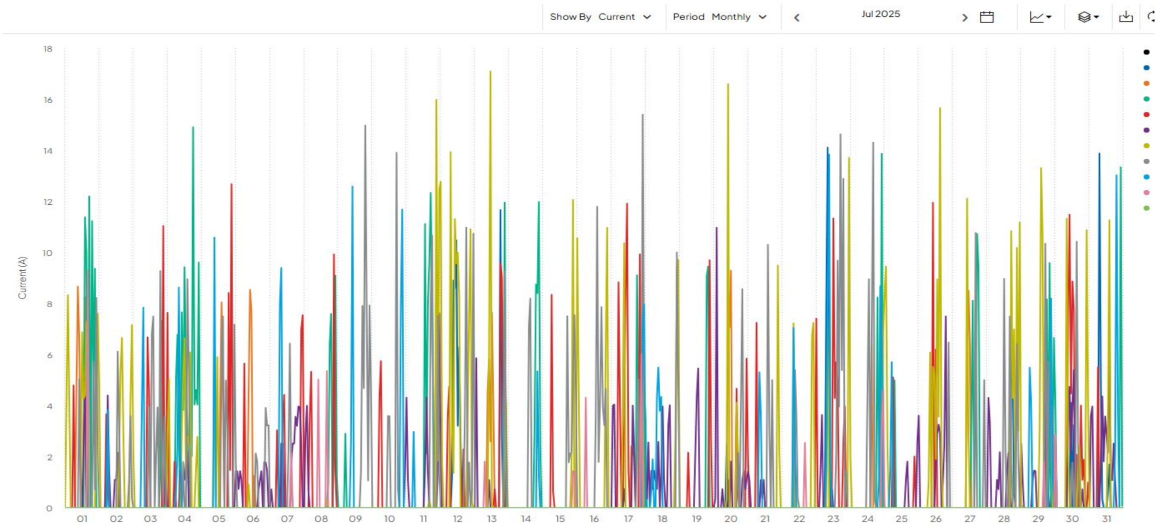


Figure 12: Screenshot of active dryers' operating trend in July 2025.

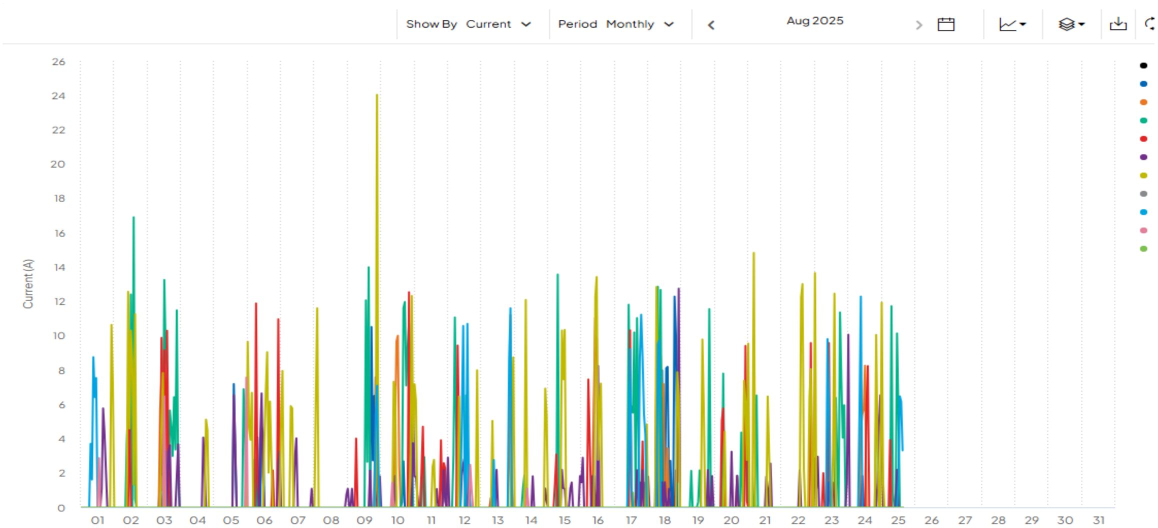


Figure 13: Screenshot of active dryers' operating trend in August 2025.

Each household exhibited distinct dryer usage patterns, including variations in weekly or monthly drying needs, time of operation, cycle duration, and frequency. These behavioral factors, being user-dependent, could not be independently monitored or controlled. Table 11 summarizes the measured data collected during the reporting period across the ten active sites.

Table 11: Summary of reporting period measured data.

Site #	Days	Minutes Heater ON	Minutes Dryer ON	Total kWh	Cycles	Average kW	kWh/ Cycle	Minute/ Cycle
1	88	229	842	20	37	5.27	0.54	23
2	89	3,161	3,950	113	45	2.14	2.50	88
3	89	4,035	5,938	219	125	3.26	1.76	48
4	64	3,365	8,228	286	194	5.11	1.48	42
5	32	472	599	27	9	3.42	2.99	67
6	89	2,117	3,066	91	37	2.59	2.47	83
7	88	7,824	9,887	366	140	2.80	2.61	71
8	89	3,752	4,694	149	61	2.39	2.45	77
9	89	1,867	10,425	162	314	5.21	0.52	33
10	88	5,359	7,588	302	134	3.38	2.25	57

Source: Project team

Dryer usage patterns observed during the reporting period were generally consistent with those recorded during the baseline period across all sites. ‘Minutes Heater ON’ represents active heating time, while ‘Minutes Dryer ON’ reflects the total normalized cycle duration.

Findings from the Reporting Period Survey

Upon completion of the reporting period, nine out of ten participants were available to be surveyed regarding their dryer usage and satisfaction with the installed technology. The majority reported no change in usage habits, continuing to operate their dryers regularly with standard sorting and settings. All participants expressed satisfaction with laundry dryness, with most noting improved drying efficiency, particularly shorter cycles except for heavier loads like towels, which occasionally required additional time. No significant operational issues were reported, though some participants experienced a brief delay of five to ten minutes before restarting the dryer after shutdown. Overall, feedback was positive, with most participants expressing interest in retaining the technology due to its potential for energy and cost savings. One participant was concerned about the future maintenance of the equipment. Responses from the participants are summarized in Table 12.

Table 12: Reporting period survey results.

Question #	Questions	Responses (10 Active Sites)
1	How many times do you use the dryer in a week?	1 load/week – 1 2–3 loads/week – 2 3–4 loads/week – 2 5–10 loads/week – 4 >10 loads/week – 0 >20 loads/week – 0
2	Do you wash clothes by type?	Separate – 8 Not separate – 1 Both – 0
3	Which option(s) do you select to operate your dryer?	Timed dry – 4 Preset dry cycle – 2 Temperature – 3
4	Are you satisfied with the dryness? If not, why are you not satisfied with dryness?	Yes – 9 No – 0
5	Did you notice any change in clothes dryness?	More dry – 8 Less dry – 0 Didn't change – 1
6	Did you notice any change in drying time?	Shorter – 7 Longer – 0 Didn't change – 2
7	Did you experience any difficulty using the product installed?	Yes – 0 No – 9
8	Do you want to keep the technology?	Yes – 8 No – 1

Source: Project team

Limitations

This study directly measured energy consumption during both the baseline and reporting periods to evaluate potential savings. However, several limitations affected the precision and scope of the analysis:

- **Lack of independent variables:** Due to the absence of measurable independent variables, an energy modeling approach was not feasible.
- **Power estimation:** Real power was not directly measured. Instead, amperage readings were used with the assumption that voltage and power factor remained constant throughout the

monitoring period. Given that the equipment operates on a single-phase power supply, its impact was assumed to be minimal.

- **Exhaust air data:** Exhaust temperature and humidity were not logged during the monitoring period, limiting the ability to perform a direct performance comparison. Installing such sensors in residential settings was constrained by space and cost.
- **Dryness assessment:** Actual moisture content of clothes was not measured. Instead, user-reported satisfaction with dryness served as a proxy.
- **Variability in dryer algorithms:** Each dryer model operates with a unique control algorithm—some modulate heat continuously, while others use ON-OFF logic. This variability influenced energy consumption patterns and complicated direct comparisons.
- **Cycle time estimation:** Drying cycles were estimated based on site-specific data and normalized to standard intervals (e.g., 15, 30, 45, 60 minutes), which may not fully reflect actual user-selected durations.

Data Analysis

The logged data revealed distinct operational behaviors across different dryer brands. Some models maintained continuous heating throughout the drying cycle using modulation, while others operated with intermittent ON-OFF heating patterns. To accurately assess performance, raw data from each site were carefully analyzed to determine cycle durations and energy usage. Site-specific dryer cycle samples in the baseline and reporting period are presented in

Appendix A: Site-Specific Dryer Operating Profiles. Three core metrics were used to evaluate dryer performance:

- Average energy use per cycle (kWh/cycle)
- Average cycle duration (minutes/cycle)
- Average power draw (kW)

The project team assumed that user behavior remained consistent throughout the study period. Figure 14 illustrates the primary control features of the dryer models included in the study.

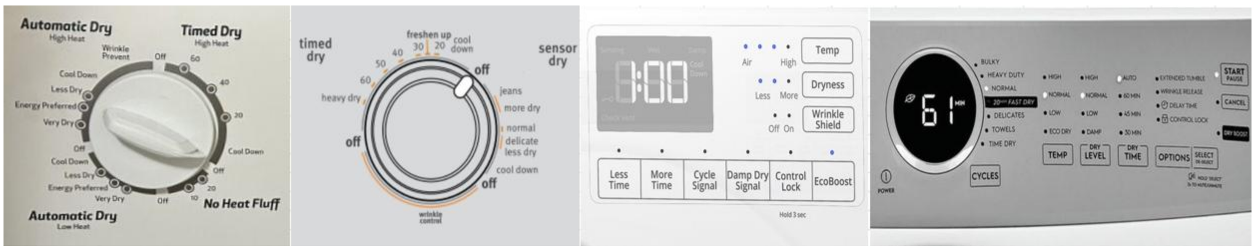


Figure 14: Primary control features of dryers used in the study.

Source: Project team

Clothes dryers typically operate through heating, tumbling/fluffing, and cooling phases. Energy consumption is minimal during tumbling and cooling. Generally, the drying cycles range from 15 minutes to over an hour, depending on user-selected settings such as temperature, dryness level, and fabric type. The following figures present three typical operating patterns observed in the logged data.

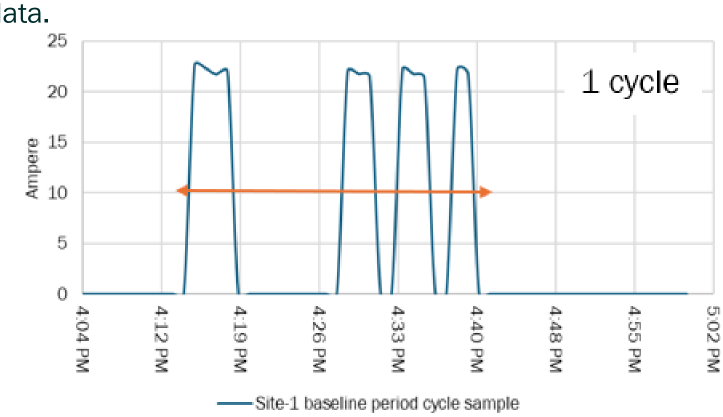


Figure 15: Typical dryer cycle, type A.

Source: Project team

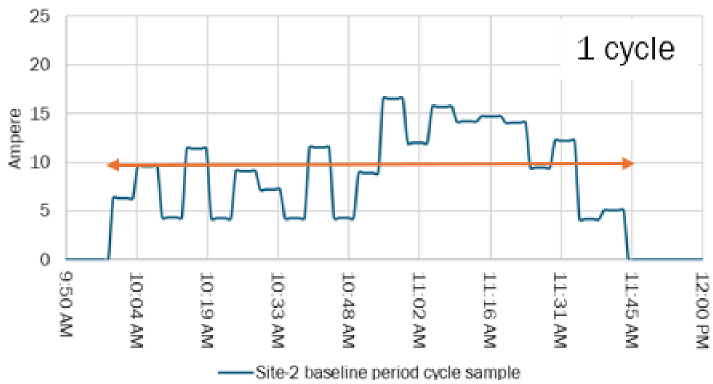


Figure 16: Typical dryer cycle, type B.

Source: Project team

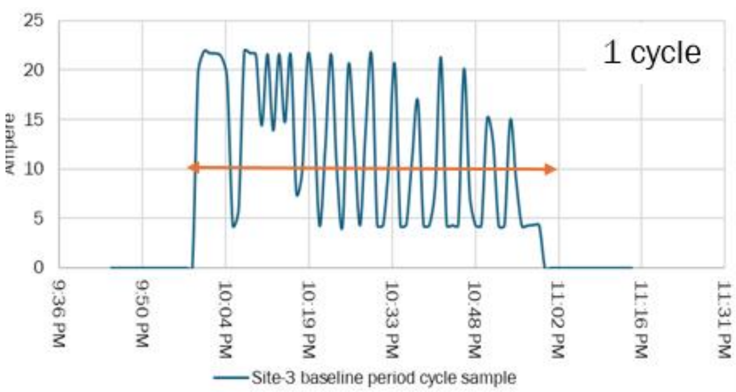


Figure 17: Typical dryer cycle, type C.

Source: Project team

Three sites using Maytag, Roper, and Whirlpool dryers (Figure 15) exhibited intermittent heating cycles. In contrast, seven sites with Electrolux dryers (Figure 16 and Figure 17) showed modulated heating behavior. These differences reflect manufacturer-specific control algorithms.

For consistent comparisons across different dryer behaviors, dryer cycle times were normalized to a minimum of 15 minutes of continuous operation. Table 13 summarizes the percentage changes in key metrics between the baseline and reporting periods. Positive values indicate reductions; negative values indicate increases.

Table 13: Comparison of baseline and reporting period.

Site #	Average kW Reduction	kWh/Cycle Reduction	Minutes/Cycle Reduction
1	1.7%	0%	13%

Site #	Average kW Reduction	kWh/Cycle Reduction	Minutes/Cycle Reduction
2	1.7%	0.5%	13.4%
3	4.3%	23.2%	16.5%
4	-7.3%	36.0%	31.2%
5	0.4%	10.3%	7.1%
6	-6.0%	16.1%	18.5%
7	5.2%	12.4%	7.4%
8	6.4%	2.3%	-2.6%
9	-2.7%	13.0%	14.7%
10	-0.002%	37.0%	25.8%
Changes from baseline	**0.2%**	**19.4%**	**15.8%**

Source: Project team

On average, the dryer controller reduced cycle time by approximately 16 percent, resulting in a 19.4 percent reduction in energy consumption per cycle. The controller operates by monitoring exhaust air temperature and humidity, terminating the heating phase once optimal dryness is achieved. This effect was observed in nine of the ten sites, with only one site showing a slight increase in cycle time. Figure 18 and Figure 19 show the comparison of cycle time between the baseline period and the reporting period. All sites except for site 7 were found to reduce cycle time. Across all sites, an average 15.8 percent reduction in cycle time was reported.

Figure 18: Comparison of cycle time.

Source: Project team

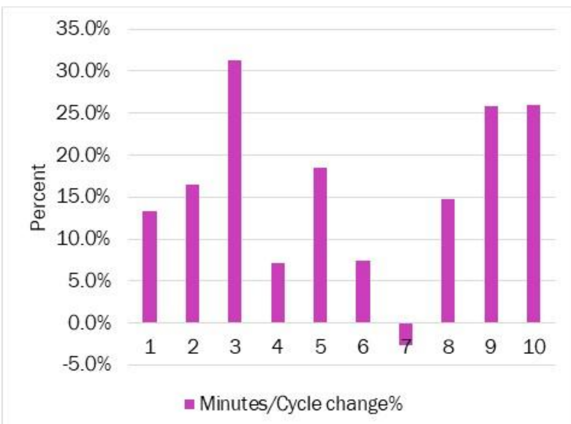


Figure 19: Comparison of minutes per cycle changes.

Source: Project team

Figure 20 and Figure 21 show the comparison of energy per cycle between the baseline and reporting periods of the ten sites. All sites demonstrated a reduction in energy use per cycle, ranging from 0.5 to 37 percent. Across all sites, the average reduction in energy consumption per cycle was 19.4 percent.

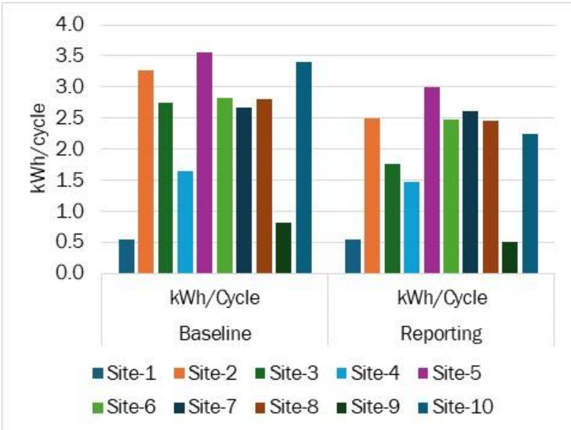


Figure 20: Comparison of energy per cycle.

Source: Project team

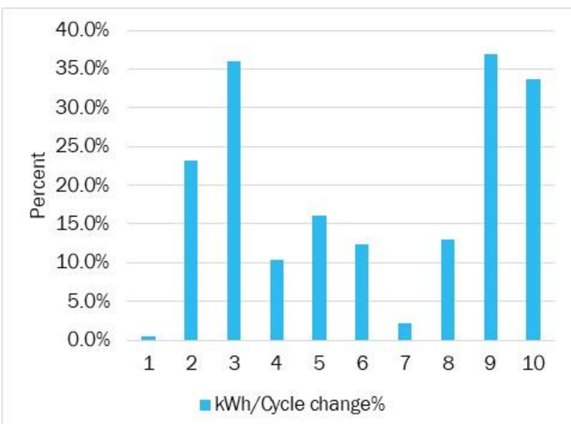


Figure 21: Comparison of energy per cycle change

Source: Project team

Figure 22 and Figure 23 show the comparison of average power logged between the baseline and reporting periods at ten sites. While five sites showed reduced average power, the remaining five experienced slight increases. Overall, the average change in power draw was a modest reduction of 0.17 percent. This result is expected, as the primary factor influencing energy savings is the duration of the cycle, rather than the magnitude of the power draw.

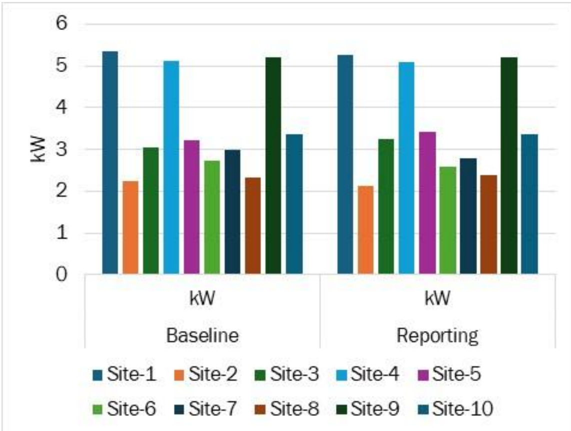


Figure 22: Comparison of average power consumption.

Source: Project team

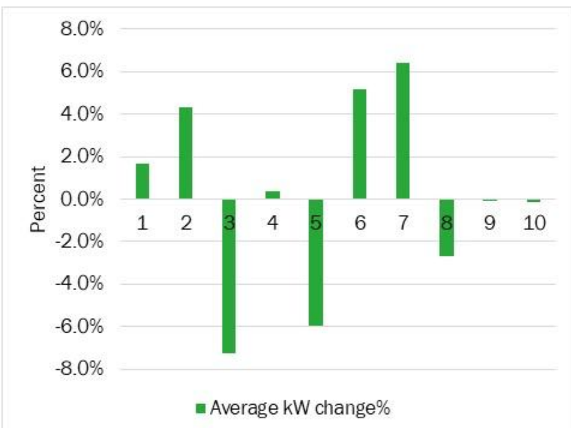


Figure 23: Comparison of average power change.

Source: Project team

Annualized Savings

Energy savings were annualized using two approaches:

- Actual usage across the ten sites
- Standardized usage based on 283 cycles/year (eTRM 2023)

Table 14 shows the annualized savings.

Table 14: Annualized savings.

Metric	Actual Usage	Standard Usage
Average annual savings per site in kWh	220	133

Source: Project team

GHG Emissions Reduction

GHG emissions reduction resulting from decreased electric energy usage was estimated using PG&E's average emissions factor of 0.400173 kg CO_2e/kWh between August 2024 and July 2025. The controller is estimated to reduce annual GHG emissions by 53.4 to 88.2 kg CO_2e per household. Table 15 shows the average annual GHG emissions reduction potential of an electric dryer controller.

Table 15: GHG emissions reduction

Metric	Actual Usage	Standard Usage
Average annual savings per site in kWh	220	133
Average annual GHG emissions reduction per site in kg CO_2e	88.2	53.4

Source: Project team

Cost-Benefit Analysis

The electric clothes dryer has an effective useful life (EUL) of 12 years on the eTRM. The controller is considered an add-on equipment and has an EUL of four years. Table 16 shows the costs and the simple payback. A nominal electric utility rate of 40 cents per kWh is used in the savings calculations.

Table 16: Cost-benefit analysis.

Criteria	Initial Cost in $	Installation Cost in $	Total Cost in $	Savings/ Year in kWh	Savings/ Year in $	EUL Years	Simple Payback Years
Actual number of cycles	150	200	350	220	88.0	4.0	4.0

Criteria	Initial Cost in $	Installation Cost in $	Total Cost in $	Savings/ Year in kWh	Savings/ Year in $	EUL Years	Simple Payback Years
Standard number of cycles	150	200	350	133	53.2	4.0	6.6

Source: Project team

Stakeholder Feedback

At the start of the baseline period, the project team conducted in-person interviews with all 19 participating households to gather insights into dryer usage habits. At the conclusion of the reporting period, follow-up interviews were conducted by phone with the 10 active participants to assess their experience with the installed technology. Survey results are summarized in the Findings section. Additionally, the installation contractor was interviewed to evaluate installation requirements. The contractor reported that the dryer controller was straightforward to install but recommended that installation be performed by a qualified electrician. Standard electrical tools—such as screwdrivers, wire cutters, strippers, wrenches, and crimpers—were required, along with appropriate personal protective equipment (e.g., insulated gloves and leather gloves). Installing the temperature and humidity sensor on the exhaust duct required particular care and skill due to the potential risk of injury from sharp metal edges.

Recommendations

The study confirms that add-on electric dryer controllers can significantly reduce energy consumption and drying time in residential settings. With an average 19.4 percent reduction in energy per cycle and 15.8 percent reduction in cycle time, this technology supports California's decarbonization goals under SB 100 by improving appliance efficiency and reducing GHG emissions. Widespread adoption could yield substantial cumulative energy savings and emissions reductions across the state.

Potential applications are as follows.

- **Utility programs:** Integrate the dryer controller into IOU incentive programs targeting residential energy efficiency. With the simple installation, the technology can be easily integrated with existing direct-install programs.
- **Low-income and disadvantaged communities**: Prioritize deployment in disadvantaged communities to enhance energy equity.
- **Retrofit market:** Promote as a retrofit solution for existing electric dryers lacking sensor-based termination.
- **Smart grid integration:** Pair with demand response programs to shift dryer usage away from peak periods.

The limitations of the current experiment are as follows.

- **Sample size:** The final sample was reduced to 10 sites, limiting statistical robustness.
- **Sensor constraints:** There was no baseline exhaust temperature or humidity data due to residential installation limitations.
- **Measurement gaps:** Ampere-based logging may miss low-current events; real power was not directly measured.
- **User behavior:** Variability in user habits and dryer models introduces uncontrolled variables. However, this variability reflects realistic usage scenarios, enhancing the relevance of the findings.
- **Dryness assessment:** The team relied on subjective user feedback rather than objective moisture content measurements.

Suggestions for future research are as follows.

- **Expanded sample:** Increase participant pool across diverse climate zones and demographics.
- **Enhanced instrumentation:** Include exhaust air temperature and humidity sensors for both baseline and reporting periods.
- **Real power monitoring:** Use power meters to capture true energy consumption.
- **Behavioral analysis:** Study user interaction with the controller and its impact on savings.
- **Algorithm optimization:** Tailor control logic to specific dryer models for improved compatibility and performance.
- **Longitudinal study:** Assess durability, long-term savings, and user satisfaction over multiple years.
- **Product design improvement:** Design the product to make plug-and-play with wireless sensors, eliminating the need for professional installation.

Conclusions

The dryer controller delivered an average of 19.4 percent energy savings and reduced cycle times by 15.8 percent across all sites without operational issues and with full user satisfaction. These results confirm the technology's effectiveness in reducing over-drying by monitoring exhaust air conditions.

While the calculated simple payback period is under seven years, lowering installation costs could shorten it further. Improving the design to make it plug-and-play with wireless sensors could eliminate the need for professional installation and improve cost-effectiveness. Additionally, IOUs' energy efficiency programs may support broader adoption through incentives. With rising electric rates, the simple payback may decrease over time.

This study provides field-validated data to inform workpaper development and support potential inclusion in statewide efficiency portfolios.

References

CA DOF. 2020. "2020 Census Data." *2020 Census Data.* Sate of California Department of Finance. https://dof.ca.gov/forecasting/Demographics/2020-census-data/#DHCA.

Calwell, Chris, and David Houghton. 2019. "ecos research." *Evaluation of Energy Saving Potential and Performance of TrickleStar® DryerSaver™.* https://cdn.shopify.com/s/files/1/0592/0070/0615/files/Ecos_Research_TrickleStar_Report_13May2019_1.pdf?v=1717543600.

CEC. 2019. *2019 California Residential Appliance Saturation Study.* https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

CEC. 2021. *California Building Decarbonization Assessment - Final Commission Report.* California Energy Commission. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

—. 2021. "SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment." *2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment.* https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

Denkenberger, David, Serena Mau, Chris Calwell, and Eric Wanless. 2011. "Residential Clothes Dryers: A Closer Look at Energy Efficiency Test Procedures and Savings Opportunities." https://www.nrdc.org/sites/default/files/ene_14060901a.pdf.

DOE. 2024. "Appendix D1 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers." *Code of Fedeal Regulations.* 10 8. Accessed 11 13, 2024. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20D1%20to%20Subpart%20B%20of%20Part%20430.

—. 2024. "Title 10 / Chapter II / Subchapter D / Part 430 / Subpart B." *Code of Federal Regulations.* 11 5. Accessed 11 13, 2024. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B.

Dymond, Christopher, Chris Calwell, Brian Spak, and Dave Denkenberger. 2014. "Clothes Dryer Testing, Testy Testing Makes for Better Transformation." *ACEEE.* https://www.aceee.org/files/proceedings/2014/data/papers/9-852.pdf.

ENERGY STAR. 2014. *ENERGY STAR Certified Clothes Dryer Eligibility.* Accessed 11 13, 2024. https://www.energystar.gov/products/clothes_dryers/key_product_criteria.

eTRM. 2023. "CA Energy Efficiency Measure Data." *SWAP003-04 Clothes Dryer, Residential.* https://www.caetrm.com/measure/SWAP003/04/.

EVO. 2022. "Efficiency Valuation Organization." *International Performance Measurement and Verification Protocol (IPMVP).* https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp.

IPMVP. 2022. "International Performance Measurement and Verification Protocol." https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp.

SGIP. 2024. *Greenhouse Gas Signal.* https://content.sgipsignal.com/download-data/.

TeGrotenhuis, Ph.D., W. 2014. "Clothes Dryer Automatic Termination Evaluation Volume 2: Improved Sensor and Control Designs." https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23616.pdf.

—. 2014. "Clothes Dryer Automatic Termination Sensor Evaluation, Volume 1: Characterization of Energy Use in Residential Clothes Dryers." *Clothes Dryer Automatic Termination Evaluation Volume 1: Characterization of Energy Use in Residential Clothes Dryers.* https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23621.pdf.

Appendix A: Site-Specific Dryer Operating Profiles

Site-1 is equipped with a Maytag electric dryer that operates based on a specific control algorithm, where the heating element cycles on and off intermittently throughout the drying process. Figure 24 illustrates approximately 30-minute drying cycles recorded during both the baseline and reporting periods. The baseline cycle was captured on May 13, 2025, while the reporting period cycle was recorded on July 8, 2025.

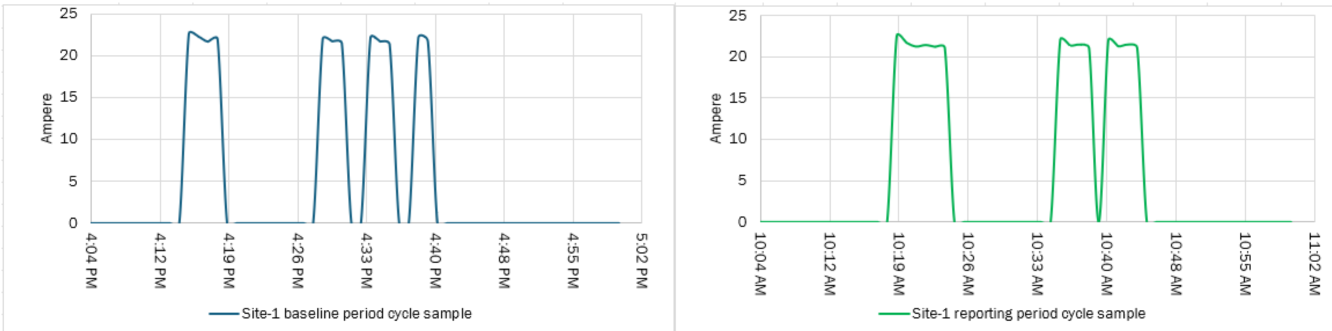


Figure 24: Site-1 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-2 is equipped with an Electrolux electric dryer. Figure 25 illustrates approximately a 120-minute drying cycle in the baseline period and a 90-minute drying cycle in the reporting period. The baseline cycle was captured on May 15, 2025, while the reporting period cycle was recorded on August 13, 2025.

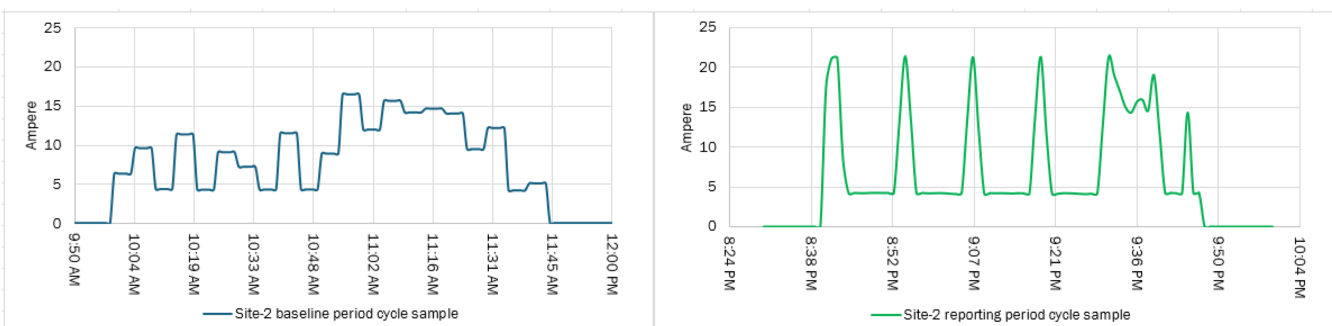


Figure 25: Site-2 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-3 is equipped with an Electrolux electric dryer. Figure 26 illustrates approximately a 60-minute drying cycle in the baseline period and a 45-minute drying cycle in the reporting period. The baseline cycle was captured on April 17, 2025, while the reporting period cycle was recorded on August 17, 2025.

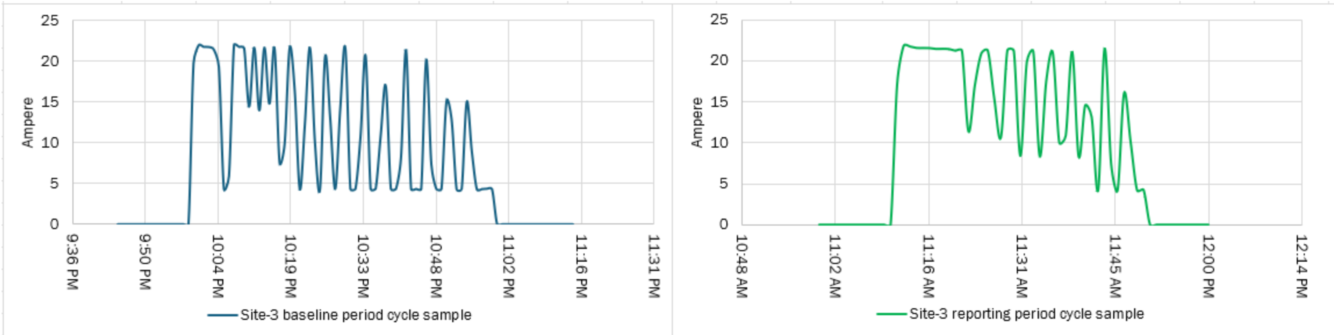


Figure 26: Site-3 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-4 is equipped with a Roper electric dryer that operates based on a specific control algorithm, where the heating element cycles on and off intermittently throughout the drying process. Figure 27 illustrates approximately 45-minute drying cycles recorded during both the baseline and reporting periods. The baseline cycle was captured on May 11, 2025, while the reporting period cycle was recorded on July 28, 2025.

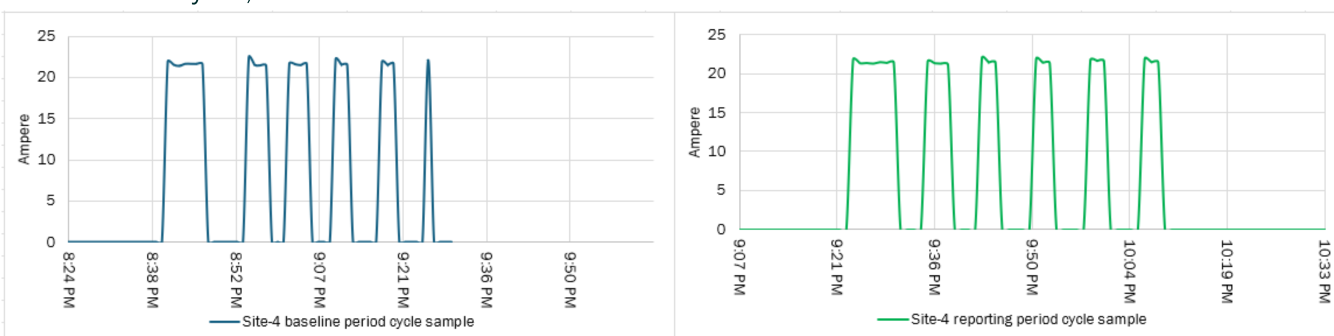


Figure 27: Site-4 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-5 is equipped with an Electrolux electric dryer. Figure 28 illustrates approximately a 90-minute drying cycle in the baseline period and a 60-minute drying cycle in the reporting period. The baseline cycle was captured on May 24, 2025, while the reporting period cycle was recorded on June 29, 2025.

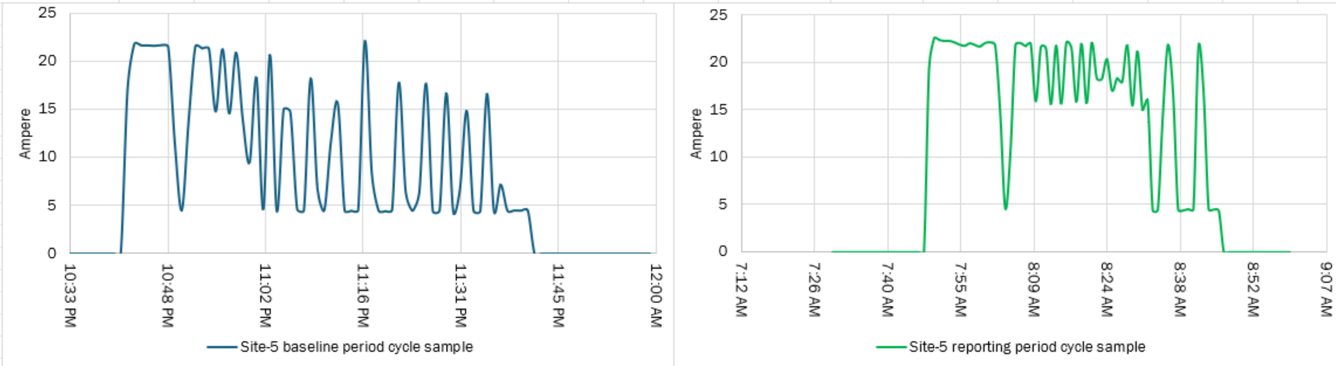


Figure 28: Site-5 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-6 is equipped with an Electrolux electric dryer. Figure 29 illustrates approximately a 120-minute drying cycle in the baseline period and a 105-minute drying cycle in the reporting period. The baseline cycle was captured on May 23, 2025, while the reporting period cycle was recorded on August 9, 2025.

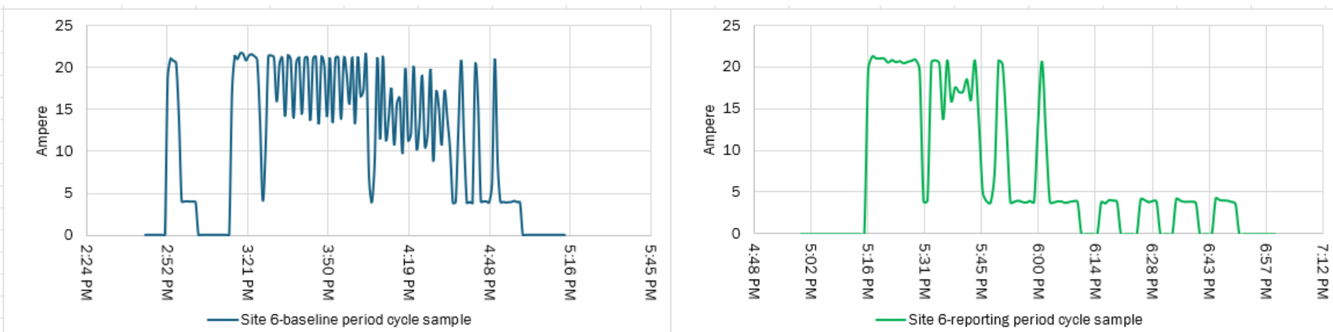


Figure 29: Site-6 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-7 is equipped with an Electrolux electric dryer. Figure 30 illustrates approximately 70-minute drying cycles in the baseline and reporting period. The baseline cycle was captured on May 19, 2025, while the reporting period cycle was recorded on August 19, 2025.

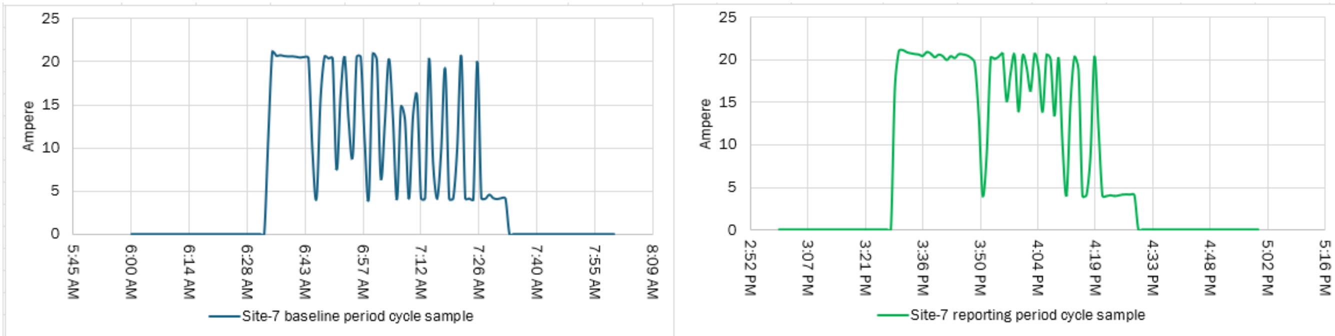


Figure 30: Site-7 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-8 is equipped with an Electrolux electric dryer. Figure 31 illustrates approximately a 105-minute drying cycle in the baseline period and a 75-minute drying cycle in the reporting period. The baseline cycle was captured on May 26, 2025, while the reporting period cycle was recorded on August 23, 2025.

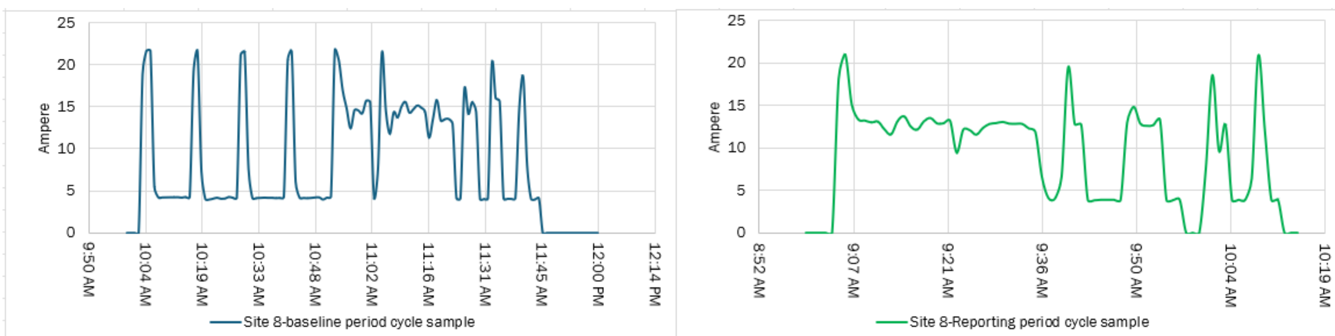


Figure 31: Site-8 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-9 is equipped with a Whirlpool electric dryer that operates based on a specific control algorithm, where the heating element cycles on and off intermittently throughout the drying process. Figure 32 illustrates approximately a 105-minute drying cycle in the baseline period and a 60-minute drying cycle in the reporting period. The baseline cycle was captured on May 19, 2025, while the reporting period cycle was recorded on August 23, 2025.

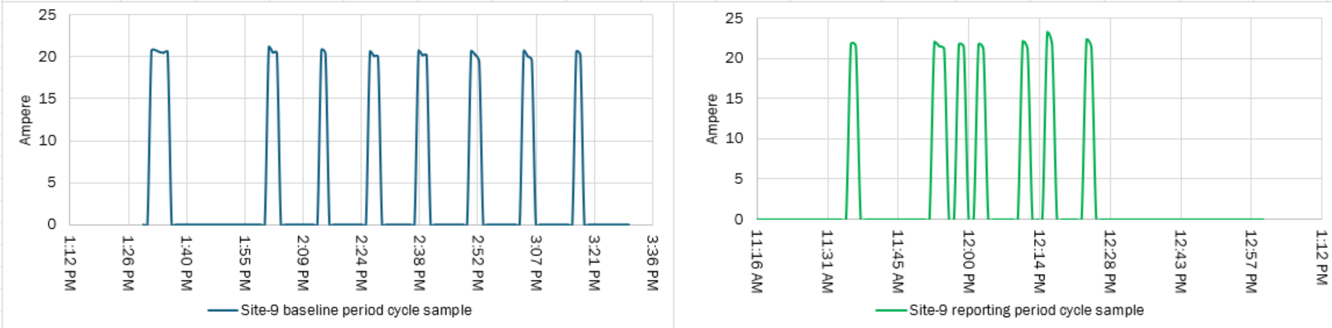


Figure 32: Site-9 dryer cycle sample of baseline and reporting periods.

Source: Project team

Site-10 is equipped with an Electrolux electric dryer. Figure 33 illustrates approximately a 45-minute drying cycle in the baseline period and a 30-minute drying cycle in the reporting period. The baseline cycle was captured on May 14, 2025, while the reporting period cycle was recorded on August 15, 2025.

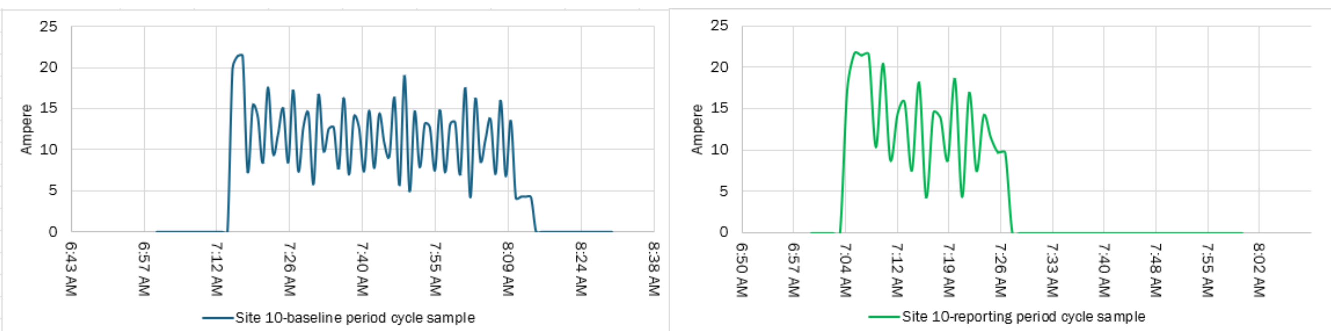


Figure 33: Site-10 dryer cycle sample of baseline and reporting periods.

Source: Project team

Appendix B: Baseline And Reporting Period Dryer Operating Profiles

Figure 34 shows the site-1 baseline period operating profile.

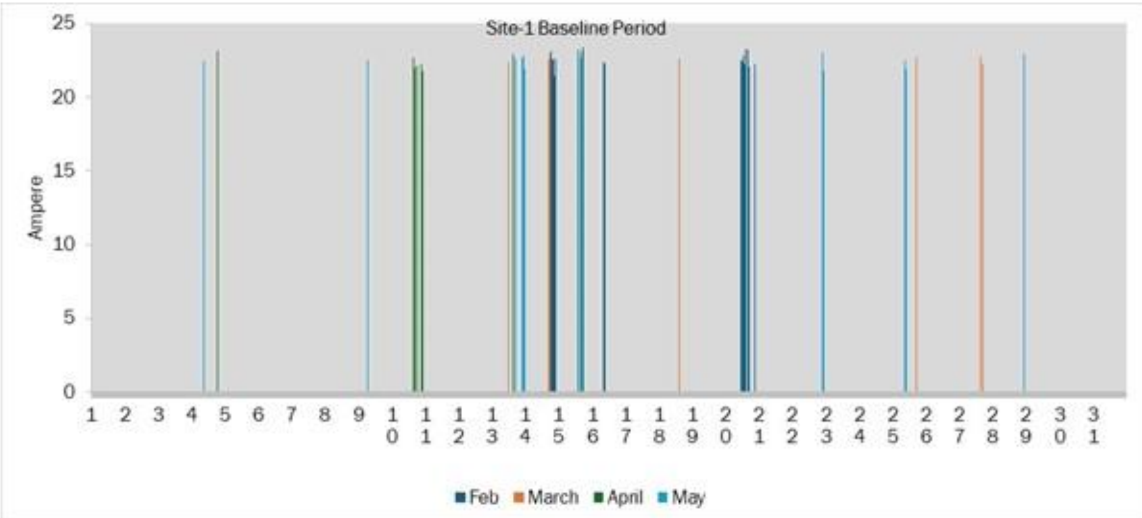


Figure 34: Site-1 baseline period profile.

Source: Project team

Figure 35 shows the site-1 reporting period operating profile.

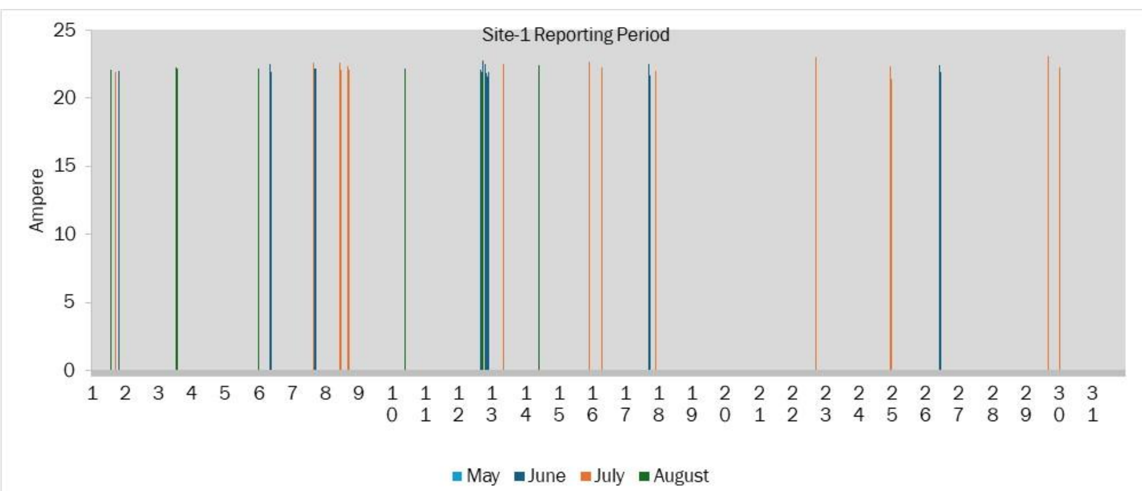


Figure 35: Site-1 reporting period profile.

Source: Project team

Figure 36 shows the site-2 baseline period operating profile.

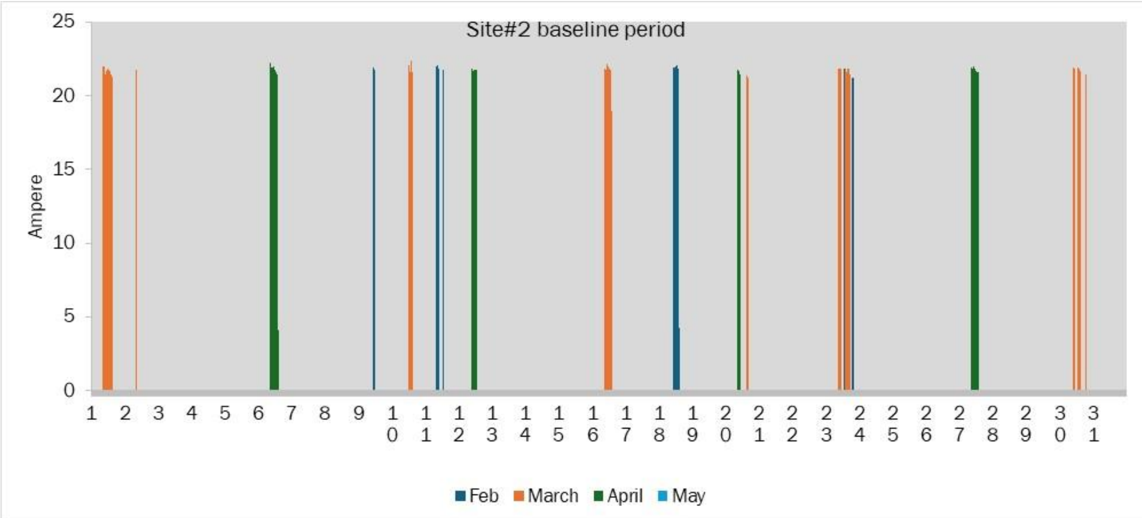


Figure 36: Site-2 baseline period profile.

Source: Project team

Figure 37 shows the site-2 reporting period operating profile.

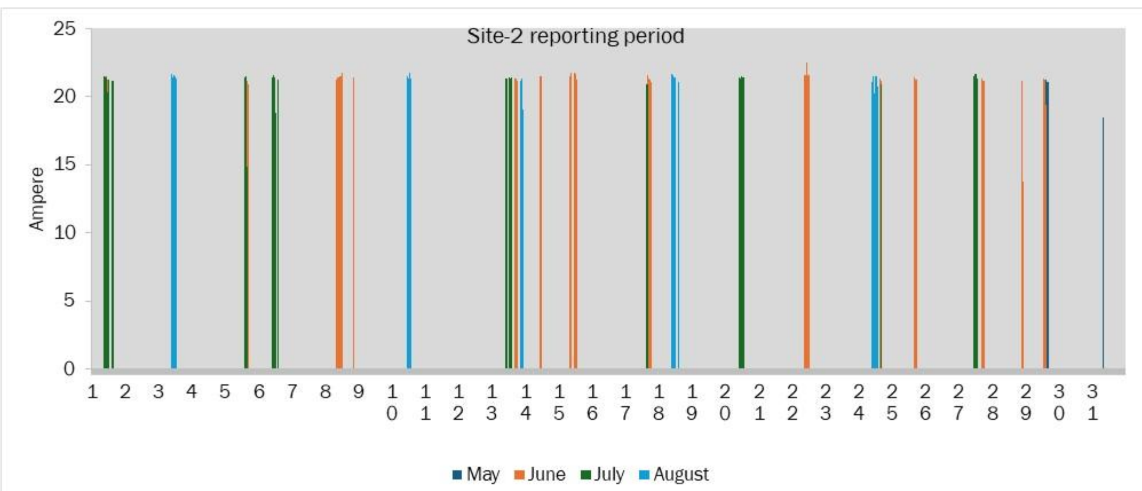


Figure 37: Site-2 reporting period profile.

Source: Project team

Figure 38 shows the site-3 baseline period operating profile.

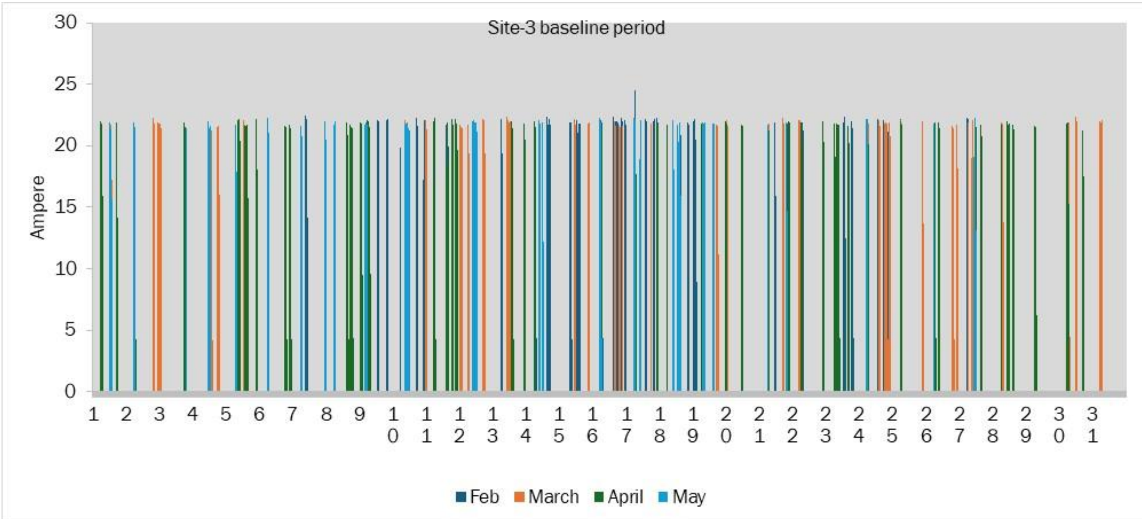


Figure 38: Site-3 baseline period profile.

Source: Project team

Figure 39 shows the site-3 reporting period operating profile.

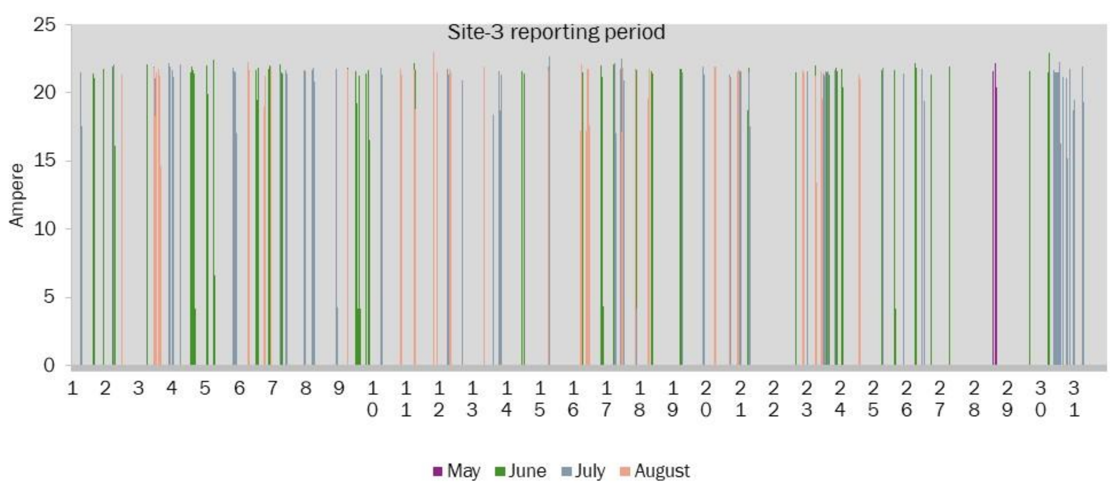


Figure 39: Site-3 reporting period profile.

Source: Project team

Figure 40 shows the site-4 baseline period operating profile.

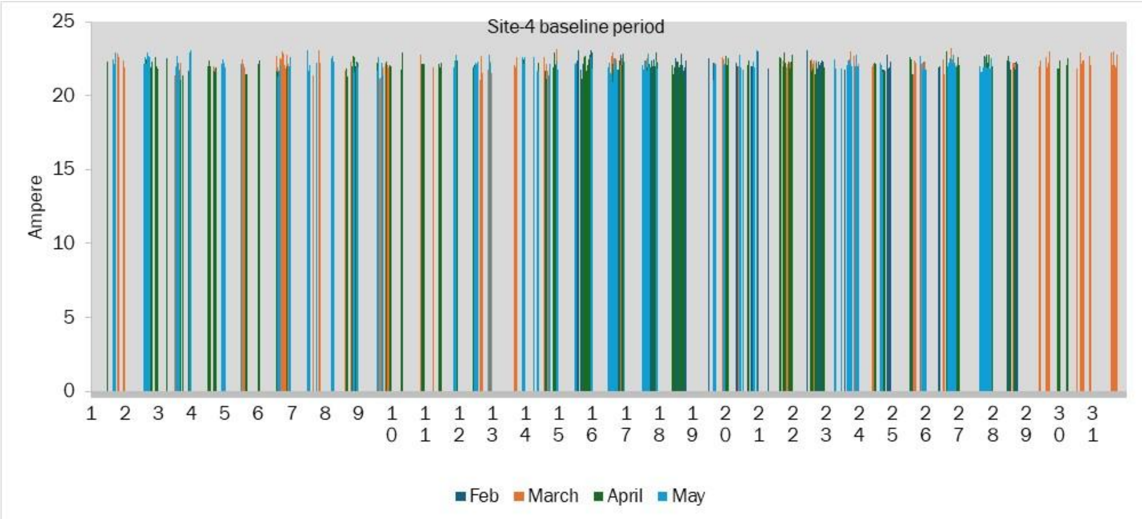


Figure 40: Site-4 baseline period profile.

Source: Project team

Figure 41 shows the site-4 reporting period operating profile.

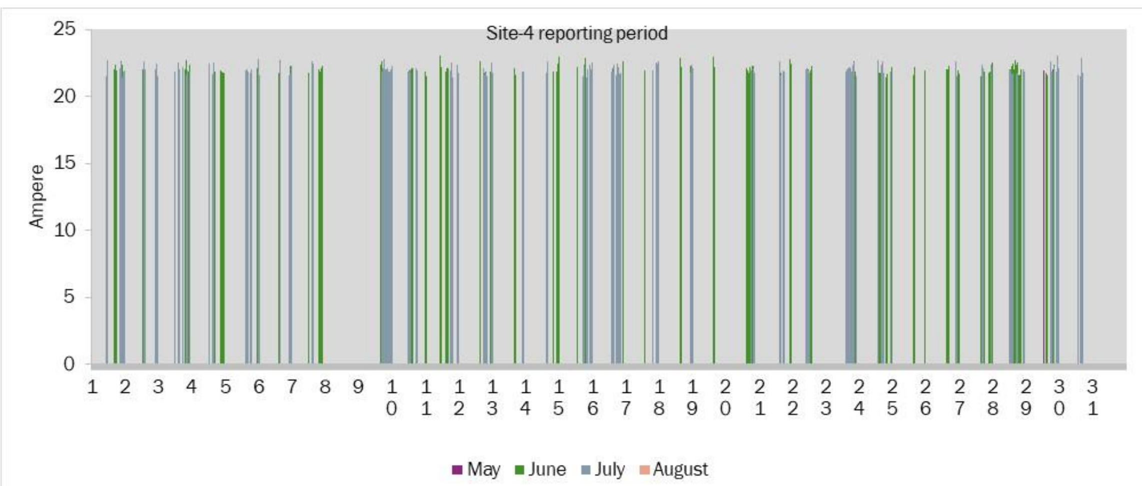


Figure 41: Site-4 reporting period profile.

Source: Project team

Figure 42 shows the site-5 baseline period operating profile.

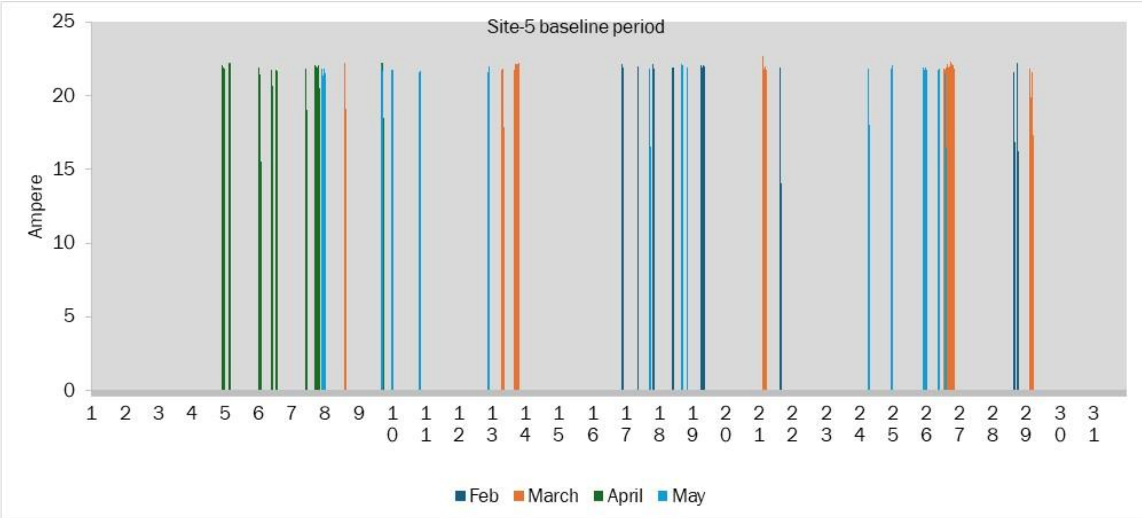


Figure 42: Site-5 baseline period profile.

Source: Project team

Figure 43 shows the site-5 reporting period operating profile.

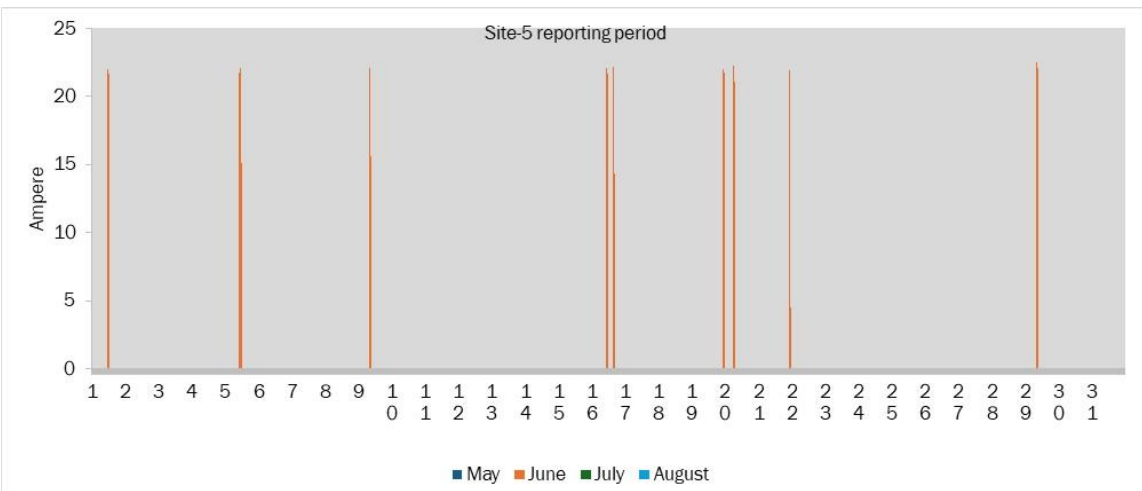


Figure 43: Site-5 reporting period profile.

Source: Project team

Figure 44 shows the site-6 baseline period operating profile.

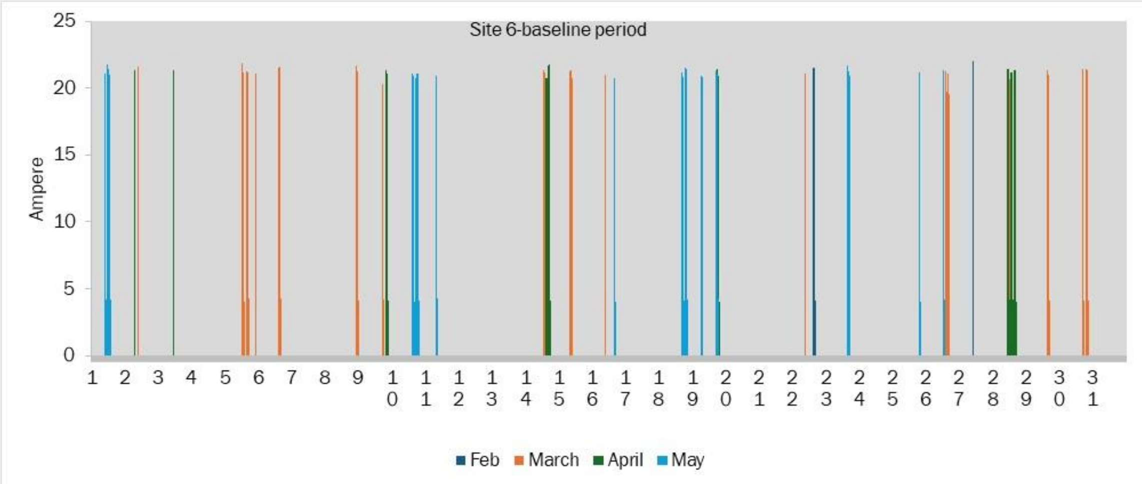


Figure 44: Site-6 baseline period profile.

Source: Project team

Figure 45 shows the site-6 reporting period operating profile.

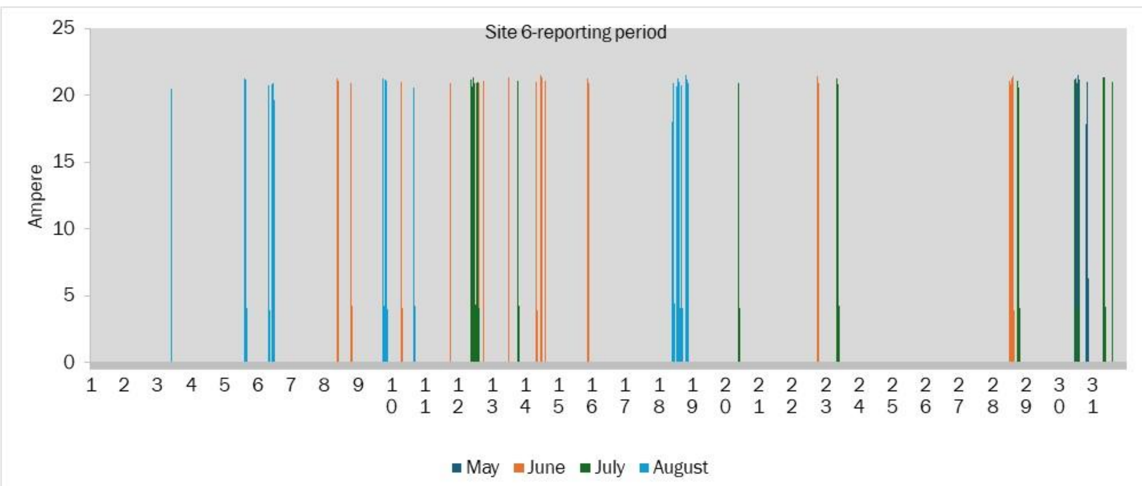


Figure 45: Site-6 reporting period profile.

Source: Project team

Figure 46 shows the site-7 baseline period operating profile.

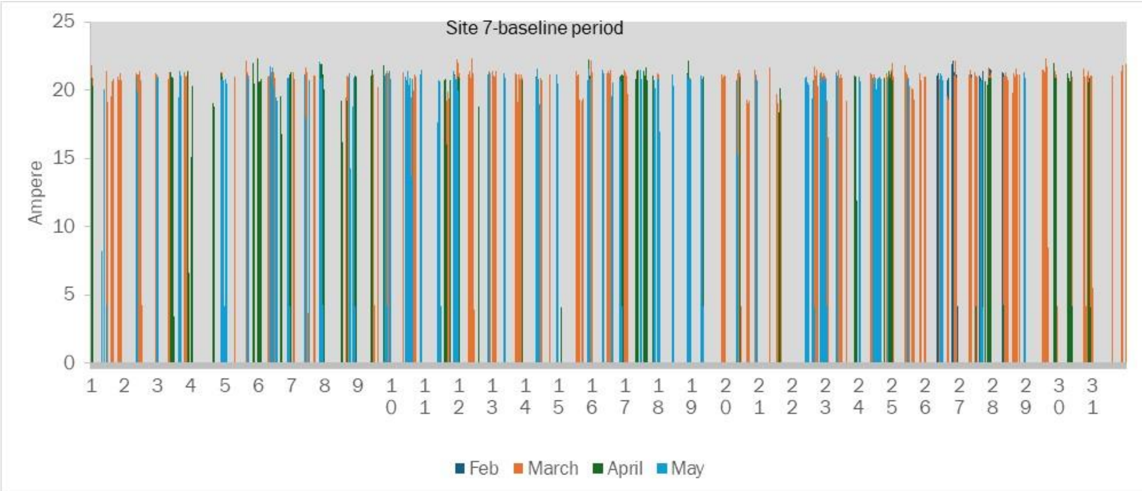


Figure 46: Site-7 baseline period profile.

Source: Project team

Figure 47 shows the site-7 reporting period operating profile.

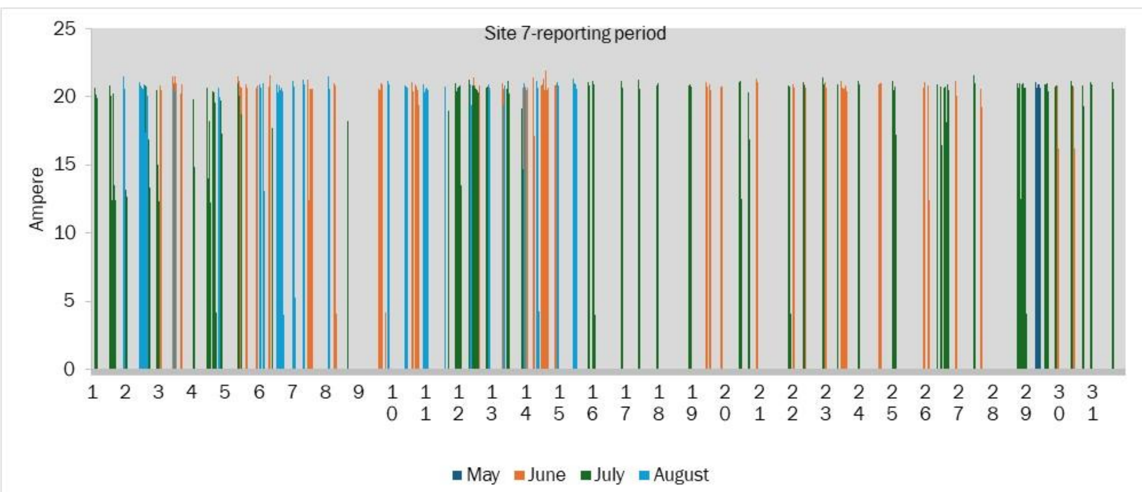


Figure 47: Site-7 reporting period profile.

Source: Project team

Figure 48 shows the site-8 baseline period operating profile.

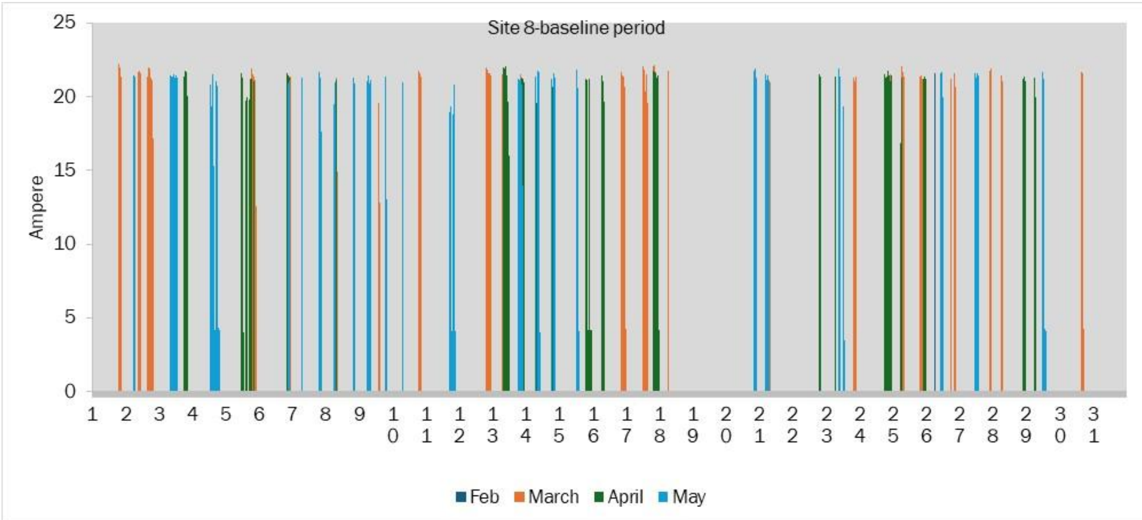


Figure 48: Site-8 baseline period profile.

Source: Project team

Figure 49 shows the site-8 reporting period operating profile.

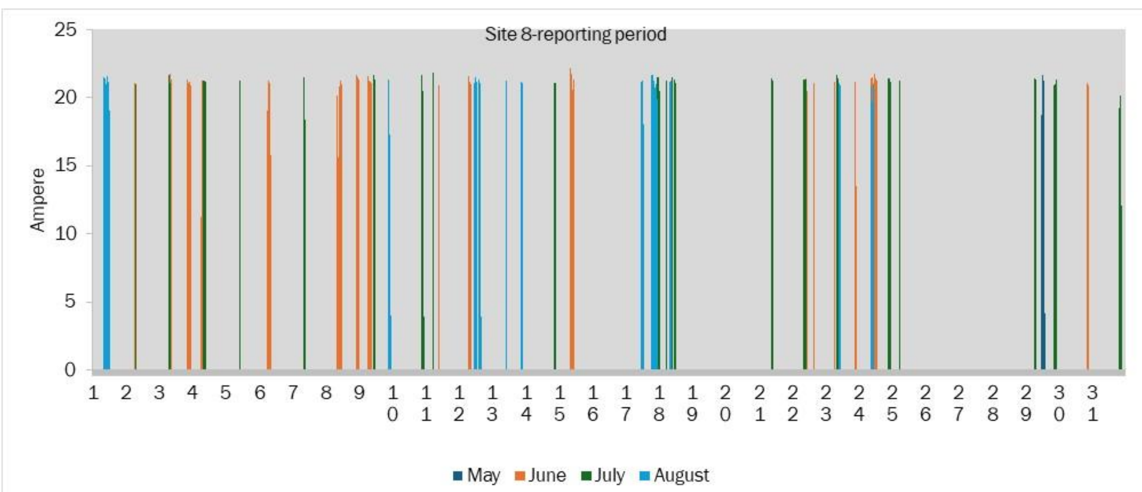


Figure 49: Site-8 reporting period profile.

Source: Project team

Figure 50 shows the site-9 baseline period operating profile.

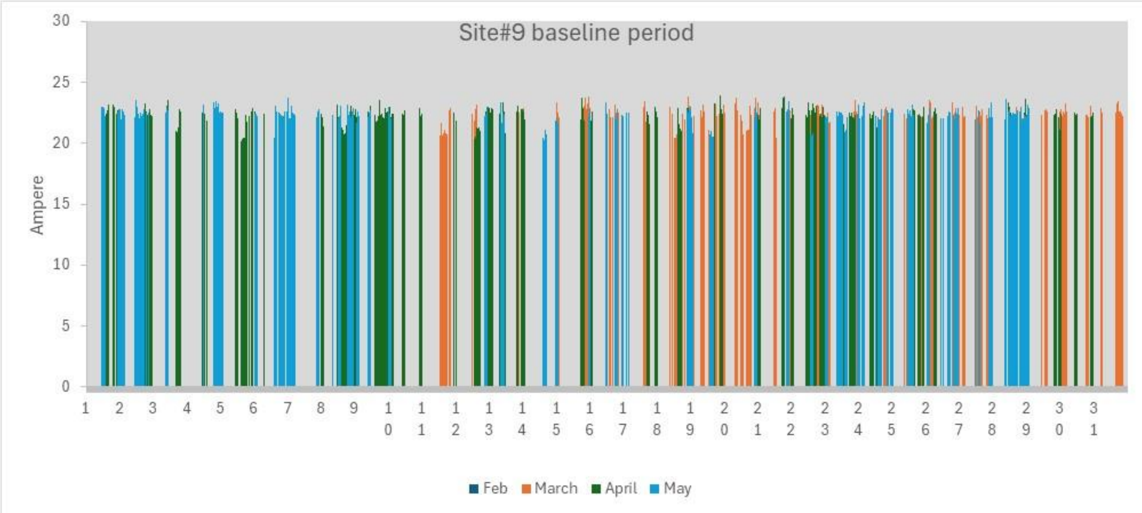


Figure 50: Site-9 baseline period profile.

Source: Project team

Figure 51 shows the site-9 reporting period operating profile.

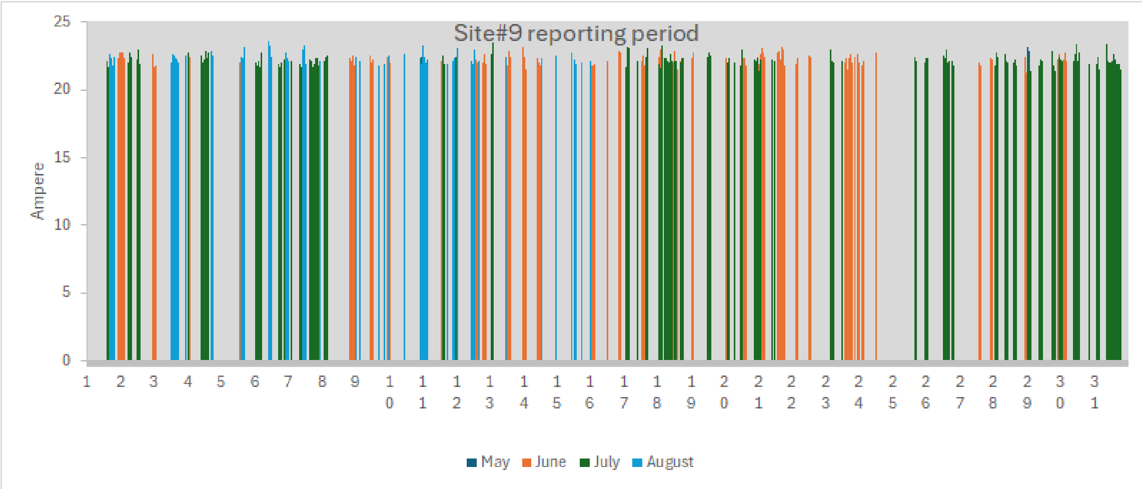


Figure 51: Site-9 reporting period profile.

Source: Project team

Figure 52 shows the site-10 baseline period operating profile.

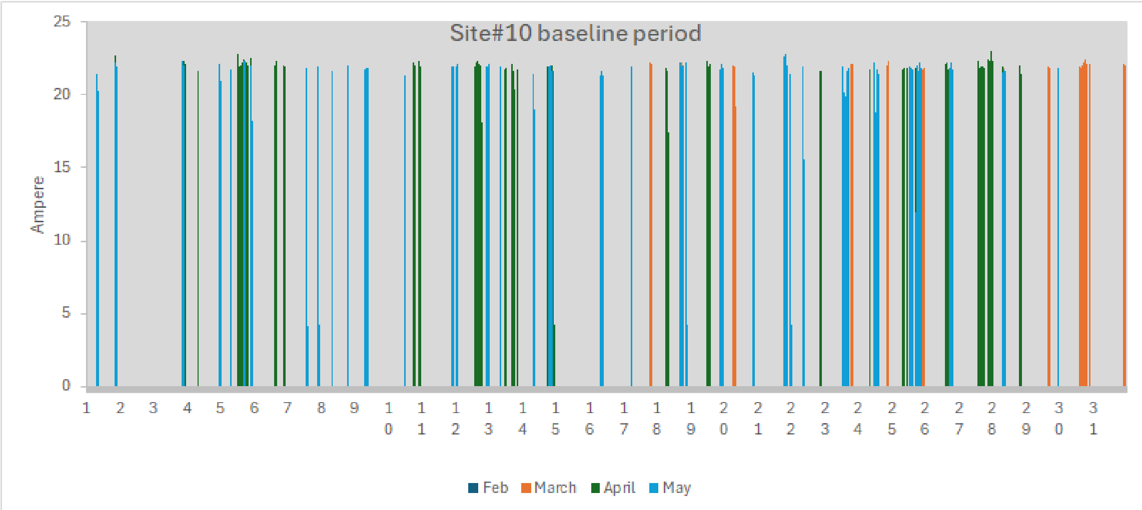


Figure 52: Site-10 baseline period profile.

Source: Project team

Figure 53 shows the site-9 reporting period operating profile.

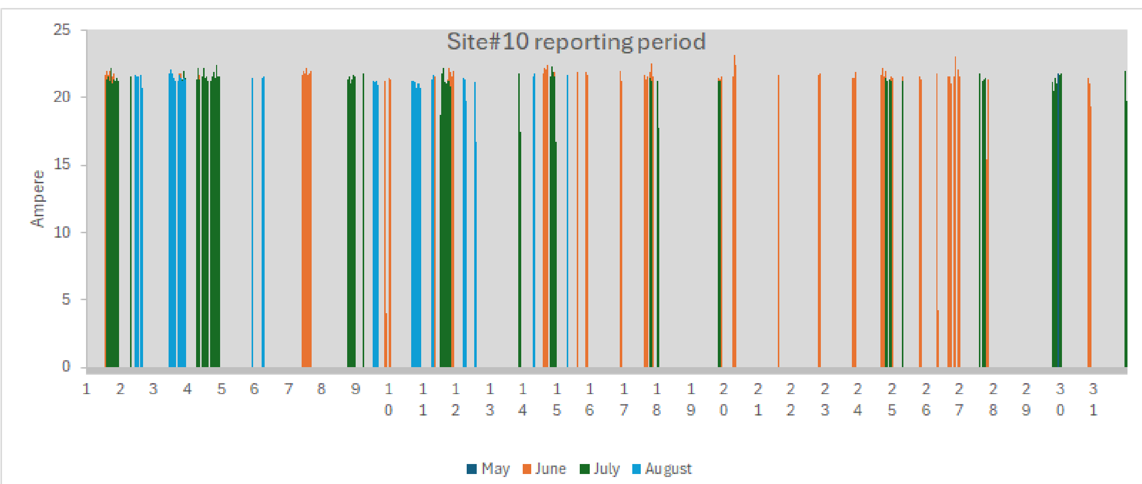


Figure 53: Site-10 reporting period profile.

Source: Project team

Appendix C: Customer Surveys

The project team conducted customer surveys to gain insights into dryer usage habits and user experience. An initial survey was carried out during the baseline period to understand participants' typical use of electric clothes dryers. A follow-up survey will be conducted at the conclusion of the post-installation testing period to assess user experience with the installed dryer controller and satisfaction with clothes dryness. The questions from the baseline and post-installation surveys are presented in Table 17Table 17 and Table 18Table 18, respectively.

Table 17: Baseline survey questions.

Number	Baseline Survey Question	Purpose
1	How long have you been using this electric clothes dryer?	To verify dryer's age and the user's experience level.
2	How many times do you use the dryer in a week?	To understand user's habit.
3	Do you wash clothes by type? If separate, how do you separate your clothes?	To understand the user's preference of washing and drying.
4	Do you dry the same load as it is washed?	To understand the user's preference of washing and drying.
5	Which option(s) do you select to operate your dryer? Options: temperature, dryness, time, preset dry cycles	To understand the user's drying preference and habit.
6	How long does it usually take to dry clothes?	To verify user's perception of clothe drying time.
7	Do you know and use 'Sensor Dry' function?	To verify user's knowledge about clothe dryer functions.
8	Are you satisfied with the dryness? If no, why are you not satisfied with the dryness?	To understand user's current satisfaction on clothe drying.
9	Are there any known issue with the dryer?	To uncover any issues the user is currently experiencing with the dryer.

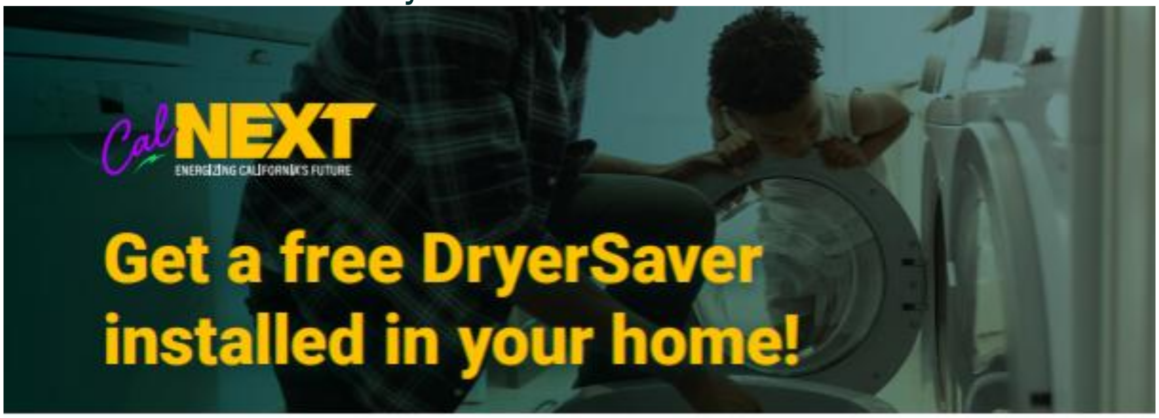
Source: Project team

Table 18: Customer experience survey questions.

Number	Post-Installation Survey Question	Purpose
1	How many times do you use the dryer in a week?	To verify dryer's age and the user's experience level.
2	Do you wash clothes by type?	To understand the user's preference of washing and drying.
3	Which option(s) do you select to operate your dryer?	To understand the user's drying preference and habit.
4	Are you satisfied with the dryness? If not, why are you not satisfied with dryness?	To evaluate the ET's performance from the user's perspective.
5	Did you notice any change in clothes dryness?	To evaluate the ET's performance from the user's perspective.
6	Did you notice any change in drying time?	To evaluate the ET's performance from the user's perspective.
7	Did you experience any difficulty using the product installed?	To understand the user's experience with the ET and any issues encountered by the user.
8	Do you want to keep the technology?	To understand the user's preference with the ET and any issues encountered by the user.

Source: Project team

Customer Recruitment Flyer



Save money by helping us study the energy savings of this new technology!

About the Study

This is a study of TrickleStar's DryerSaver for homeowners with existing electric clothes dryers willing to participate in tests of the new technology. The DryerSaver is a monitoring device that controls the drying time of an electric clothes dryer. Our test will evaluate how DryerSaver prevents excess dryer use and lowers energy costs, and you can be part of it!

Who is Qualified?

- ☑ The household has an existing electric dryer.
- ☑ The homeowner participates in a short survey about how they use their electric clothes dryer.
- ☑ Let us monitor the power consumption of the dryer for around four months.
- ☑ We will install the DryerSaver onto the electric clothes dryer at no cost to you!

What You'll Receive

A DryerSaver

$100

A $100 gift card for your participation

A report on estimated dryer energy savings from before and after installation

To learn more or to participate in the study, please contact us at et_info@aesc-inc.com.

About CalNEXT

CalNEXT is an emerging technology program funded by Investor-Owned Utilities in California. CalNEXT's vision is to identify emerging technology trends and bring commercially available technologies to the energy efficiency program portfolio.

v240430

Appendix D: Field Safety Protocols

All fieldwork conducted under this project adhered to the safety standards established by the sponsoring IOU. The following procedures were implemented to ensure personnel safety and regulatory compliance:

- **Safety orientation:** The project team received formal safety training from the program administrator, covering site-specific hazards and procedural requirements.
- **Risk assessment:** A comprehensive risk assessment was performed prior to site activities. This assessment identified potential hazards and outlined mitigation strategies, including required personal protective equipment (PPE), safety gear, and approved tools and techniques.
- **Site inspection:** The project sponsor conducted a pre-deployment inspection to verify site readiness and compliance with safety protocols.
- **Safety observations:** Monthly safety audits were performed by the program administrator, with at least one observation per crew per project site.
- **Tailboard meetings:** Prior to initiating any site work, the project team conducted tailboard meetings to review the work plan, identify critical tasks, discuss hazard controls, confirm required PPE, and reinforce stop-work authority.