Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q3 – Q4 2024

Prepared by:
Southern California Edison (U-338-E)

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Abbreviations and Acronyms

AC	Air Conditioning
ACEEE	American Council for an Energy-Efficient Economy
ADR	Automated Demand Response (aka Auto-DR)
AHRI	Air Conditioning, Heating, and Refrigeration Institute
AHU	Air-Handling Unit
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
API	Application Program Interface
ASHRAE	American Society of Heating and Air Conditioning Engineers
ASP	Automation Service Provider
AT	Advanced Technology
AutoDR	Automated Demand Response
BAN	Building Area Network
BBI	Better Buildings Initiative
BCD	Business Customer Division
BE	Building Electrification
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BOD	Biochemical Oxygen Demand
BTO	Building Technology Office
C&S	Codes and Standards
CAISO	California Independent System Operator
CARE	California Alternate Rates for Energy
CASE	Codes and Standards Enhancement
CCS	Conditioned Crawl Spaces
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CZ	Climate Zone
D.	Decision (CPUC)
DAC	Disadvantaged Community
DER	Distributed Energy Resource
DF	Demand Flexibility
DOE	Department of Energy
DR	Demand Response
DRAS	Demand Response Automation Server
DRLIMFH	Deep Retrofits in Low-Income Multi-Family Housing
DRMEC	Demand Response Measurement and Evaluation Committee
DRMS	Demand Response Management System
DRRC	Demand Response Research Center
DSM	Demand-Side Management
EDF	Environmental Defense Fund
EE	Energy Efficiency
EEC	Energy Education Center
EERP	Energy Efficient Retrofit Packages
EM&T	Emerging Markets & Technology
EMCB	Energy Management Circuit Breaker
EMS	Energy Management System

EPA	Environmental Protection Agency
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
ESA	Energy Savings Assistance
ET	Emerging Technologies
ETCC	Emerging Technologies Coordinating Council
EVSE	Electric Vehicle Supply Equipment
EVTC	Electric Vehicle Test Center
EWH	Electric Water Heater
FDD	Fault Detection and Diagnostics
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
GIWH	Grid Integrated Water Heater
GWP	Global Warming Potential
HAN	Home Area Network
HEMS	Home Energy Management System
HFC	Hydrofluorocarbons
HIL	Hardware-In-The-Loop
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IALD	International Association of Lighting Designers
IAQ	Indoor Air Quality
IDSM	Integrated Demand-Side Management
IESNA	Illuminating Engineering Society of North America
IoT	Internet of Things
IOU	Investor-Owned Utility
kW	Kilowatt
kWh	Kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LF	Load Flexibility
LIMF	Low-Income multi-family
M&V	Measurement and Verification
MF	Multi-Family
MPC	Model Predictive Control
MSO	Meter Services Organization
MW	Megawatt
NDA	Non-Disclosure Agreement
NEEA	Northwest Energy Efficiency Alliance
NEM	Net Energy Metering
NG	Natural Gas
NMEC	Normalized Metered Energy Consumption
NPDL	New Product Development & Launch
NREL	National Renewables Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
OAT	Otherwise Applicable Tariff
OCST	Occupant-Controlled Smart Thermostat
OEM	Original Equipment Manufacturer
OP	Ordering Paragraph
OpenADR	Open Automated Demand Response

OTE	Oxygen Transfer Efficiency
PC	Personal Computer
PCT	Programmable Communicating Thermostat
PDR	Proxy Demand Response
PEV	Plug-In Electric Vehicle
PG&E	Pacific Gas and Electric
PLMA	Peak Load Management Alliance
PLS	Permanent Load Shift
PMS	Property Management System
PRP	Preferred Resource Pilot
PSPS	Public Safety Power Shutoffs
PTR	Peak Time Rebate
PV	Photovoltaic
QI/QM	Quality Installation/Quality Maintenance
RDD&D	Research Development, Demonstration and Deployment
RESU	Residential Energy Storage Unit
RFI	Request for Information
RPS	Renewable Portfolio Standard
RSO	Revenue Services Organization
RTU	Rooftop Unit (air conditioning)
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SEER	Seasonal Energy Efficiency Ratio
SEPA	Smart Electric Power Alliance
SGIP	Self-Generation Incentive Program
SME	Subject Matter Expert
SMUD	Sacramento Municipal Utility District
SoCalGas	Southern California Gas Company
SONGS	San Onofre Nuclear Generating Station
SPA	Special Project Agreement
T-24	Title 24 (California building energy efficiency code)
TES	Thermal Energy Storage
TRL	Technology Readiness Level
TOU	Time of Use
TTC	Technology Test Center
UCOP	University of California – Office of the President
UL	Underwriters Laboratories
USGBC	U.S. Green Building Council
VCAC	Variable-Capacity Air Conditioning
VCHP	Variable-Capacity Heat Pump
VCRTU	Variable-Capacity Roof Top Unit
VEN	Virtual End Node
VNEM	Virtual Net Energy Metering
VRF	Variable Refrigerant Flow
VTN	Virtual Top Node
WW	Wastewater
WWTP	Wastewater Treatment Plant
XML	Extensible Markup Language
ZNE	Zero Net Energy

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1. Summary

Southern California Edison (SCE) submits this Q3 – Q4 2024 semi-annual report in compliance with Ordering Paragraph (OP) 59 of the California Public Utilities Commission (CPUC) Demand Response Decision (D.) 12-04-045, dated April 30, 2012. That Decision directed SCE to submit a semi-annual report regarding its demand response (DR) Emerging Markets and Technology (EM&T) projects by March 31 and September 30 of each program year. The SCE Customer Programs and Services (CP&S) organization at SCE oversees the EM&T program's activities, which focus on advancing DR-enabling technologies for SCE's programs, tariffs, and studies. The EM&T program is now continuing with the CPUC's four-year approved authorization from (D.) 23-12-005, dated December 14, 2023.

The SCE DR EM&T program invests in accelerating the deployment of innovative new DR technologies, software, and system applications that may enable cost-effective customer participation and performance in SCE's time-variant retail rates and DR pilots, programs, and tariffs. The EM&T program funds third-party research, market studies, the assessment of consumer technologies and advanced DR communications protocols, and conducts scaled demonstrations, equipment field trials, and laboratory tests. These activities help enable the innovative high-tech and consumer market participants to adopt DR methods and standards that advocate for continuous improvement in DR technological innovation.

The EM&T program's core investment strategies align with the guidance from D.17-12-003, and the strategies facilitate DR-enabling technology market adoption through education, in-situ field testing, assessing customer perspectives, understanding of market barriers, technology transfer, and increased customer and program adoption in DR programs and tariffs. The learnings and results from each activity, study, and assessment type are made publicly available and are effectively disseminated via virtual presentations and in-person summits and forums to energy stakeholders who can act upon these results (including investors, technology developers, customers, local governments, and policymakers).

The five EM&T core investment strategies are as follows:

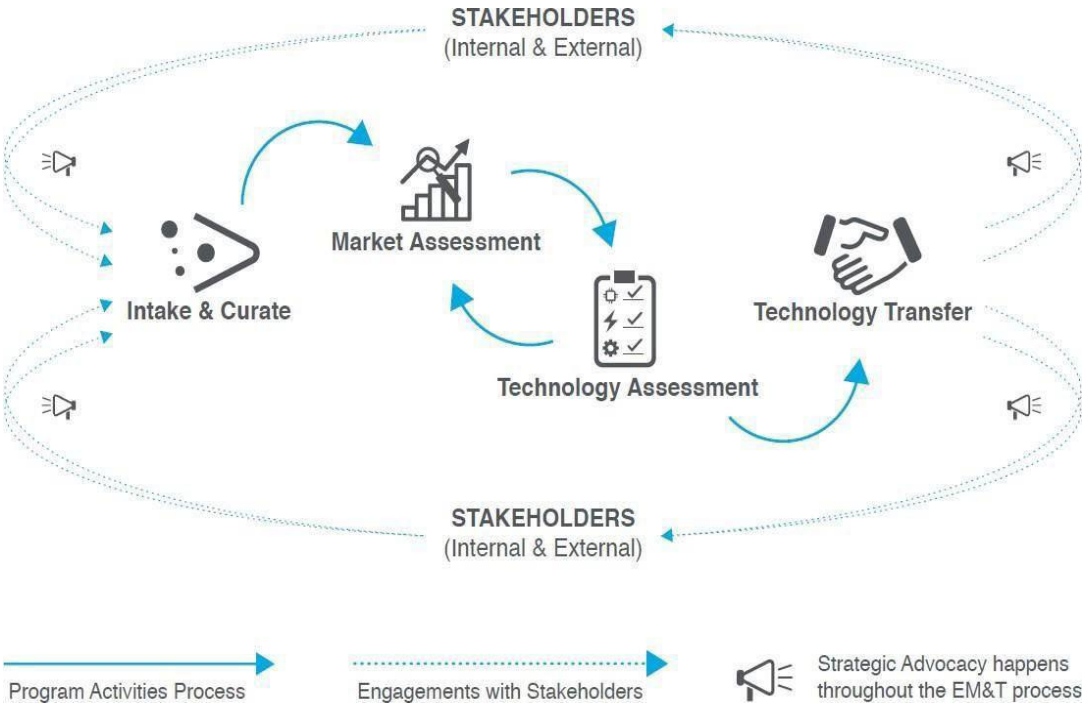
- Intake and Curation: Identifies studies, projects, or collaborations for inclusion in EM&T's portfolio and selects which ones to fund based on a well-informed understanding of the broader industry context.

- Market Assessments: Create a better understanding of the emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices.

- Technology Assessments: Assess and review the performance of DR-enabling technologies through laboratory and field tests, and demonstrations designed to verify or enable DR technical capabilities.

- Technology Transfer: Advances DR-enabling technologies to the next step in the adoption process, including raising awareness, developing capabilities, and informing stakeholders during the initial stages of emerging technology development for potential DR program and product offerings.

- Strategic Advocacy: Actively supports key market actors to integrate DR-enabling emerging technologies into their decisions, including promoting DR-enabling technologies for program adoption and supporting the development of open industry standards (Note: Strategic Advocacy is embedded in all the EM&T projects and occurs throughout the stakeholder process).



EM&T Program's Current Portfolio Investment Approach

The following table lists the EM&T projects described in this report that were initiated and in progress during the Q3 – Q4 2024 period. The table also identifies each project with the singular or bundled core EM&T Investment Category that each project addresses to facilitate the continued development of DR emerging technologies:

Project ID	Project Name	EM&T Investment Category
In-Progress Projects		
DR19.11	LOC-GFO-19-301-4 Optimizing Heat Pump Load Flexibility	Market Assessment Technology Assessment
DR21.03	Dynamic Rate Pilot	Technology Assessments Technology Transfer
DR22.02	HP-Flex: Next Generation Heat Pump Load Flexibility DR	Market Assessments Technology Assessments
DR23.01	DR-TTC Dynamic HVAC Test Chamber	Technology Assessments Technology Transfer
DR23.03	Achieving Integrated and Equitable Decarbonized Loads with the CalFlexHub	Market Assessments Technology Assessments
DR24.01	Behind the Meter Optimization of Load Technologies (BOLT) Study	Market Assessments Technology Assessment
Projects Completed		
DR19.08	Grid Responsive Heat Pump Water Heater Study	Technology Assessments Technology Transfer
DR23.02	Flick Power Study	Market Assessments Technology Assessments

EM&T Program Projects Investment Categories

SCE works collaboratively with the electric California Investor-Owned Utilities (IOUs), and with other DR research organizations, national laboratories, trade allies, and state agencies, to leverage and avoid duplication of their research of innovative DR technologies, concepts, and software that operate in parallel with the EM&T program. The EM&T program has successfully leveraged and adopted parallel activities funded from the California Energy Commission's (CEC) Electric Program Investment Charge (EPIC) program, as well as the Department of Energy's (DOE) Building Technology Office (BTO) and other state and federal research grant opportunities conducted at the DOE's national laboratories.

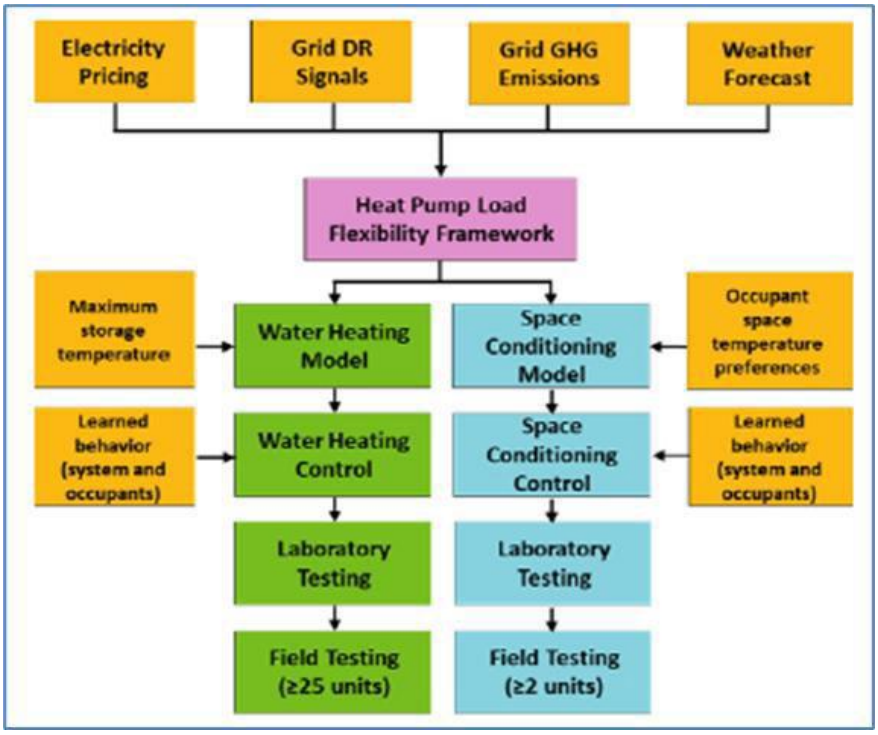
In accordance with the CPUC direction for the reporting of the DR EM&T program, this report covers the SCE DR EM&T program activities during the period between July 1, 2024, and December 31, 2024, for Q3 and Q4 of program year 2024.

1. Projects Continued Q3 – Q4 2024

DR19.11 LOC-GFO-19-301-4 Optimizing Heat Pump Load Flexibility

Overview

This CEC EPIC project which was awarded to UC Davis and which SCE is co-funding will develop, test, and demonstrate an open-source framework for heat pump load flexibility controls that will be employed for both Advanced Water Heating Controls (AWHC) and Advanced Space Conditioning Controls (ASCC). The goal is to provide a common platform that can be leveraged to manage residential electricity use across multiple types of equipment and devices. The control system optimizes heat pump operation based on: 1) Building owner/occupant preferences, comfort, and use patterns; 2) Electricity pricing, including time-of-use schedules and/or hourly or sub-hourly price signals; 3) Electricity grid needs, which may be reflected in ways other than price signals (e.g. demand response (DR) signals; 4) Electricity grid real-time greenhouse gas (GHG) emission rates; and 5) Weather data (current and forecasted).



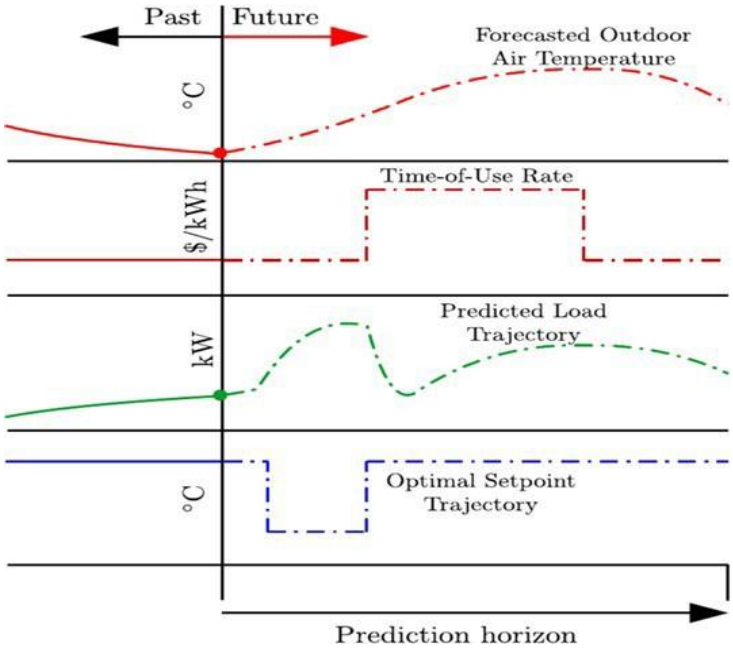
Overview of Heat Pump Load Flexibility Framework

Tackling both space conditioning and water heating controls from a common framework is useful and efficient, as most of the data needed for a heat pump load controller (e.g., electricity pricing, grid DR signals, grid emissions, weather) are not specific to the heat pump end-use type. By applying one framework to both water heating and space conditioning equipment, the project will demonstrate the

scalability and futureproofing of heat pump load control systems that are compatible with future investments in synergistic technologies. In this way, designing both water heating and space conditioning controls within a single framework will facilitate future integration of additional equipment and simplify the process of obtaining, configuring, and monitoring advanced controls.

The project vision is to develop AHWC and ASCC based on a model predictive control strategy and compare their performance to basic and advanced rule-based controls. Model predictive controls (MPC) are a state-of-the-art control optimization system. In contrast to rule-based controls, MPCs have a dynamic model that represents the specific system they control and can be adapted over time, based on site-specific data.

The MPC system uses the dynamic model to predict how the system will need to operate over a given time horizon in response to exogenous inputs, such as a local weather forecast. The MPC then calculates the optimal process control outputs based on the specified optimization objective (e.g., minimize cost, GHG emissions), which includes constraints for occupant preferences and equipment limitations.



Modelling Predictive Control Optimization

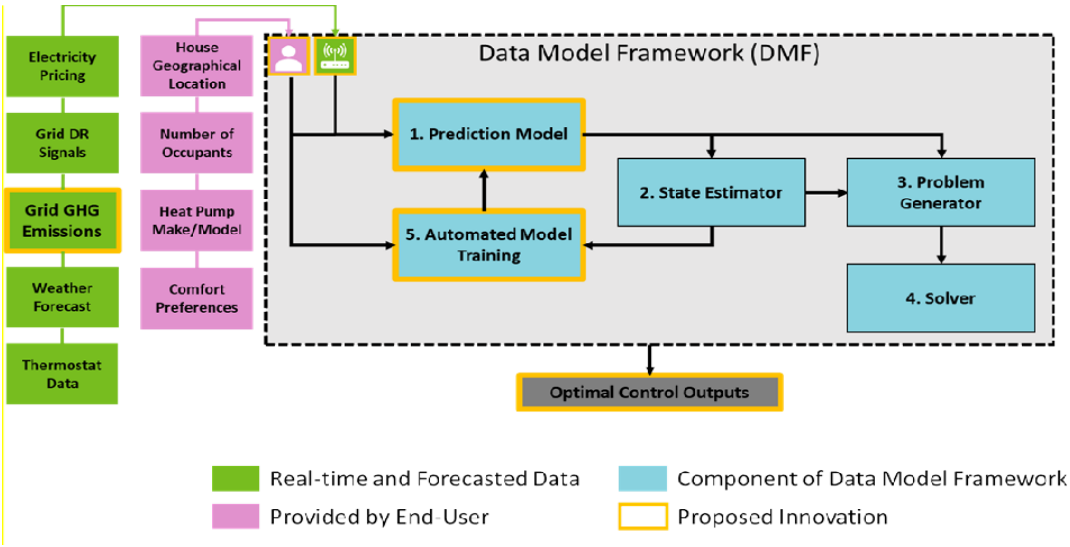
This project will develop an open-source turn-key MPC system that will be easy to use and will eliminate the need for installers or end-users to have subject matter expertise in MPC or heat pump systems. The proposed data model framework (DMF) will simplify the configuration, setup, and maintenance process for new heat pump systems that will have load flexibility capabilities. Load flexibility controls offer a way for customers to shift consumption to times of day with lower rates without compromising their comfort. For load flexibility controls to be widely adopted, building occupant preferences must be satisfied.

The AWHC control modulates hot water tank storage temperature to store thermal energy and achieve the optimal system performance, where the optimization is based on a utility price schedule or signal, a GHG emission signal, and a utility DR signal. The ASCC will modulate the housing unit's temperature setpoint to store thermal energy and achieve the optimal system performance, where the optimization is based on utility price schedules or signals, GHG emission signal, and utility DR signals.

Demonstration of the technology will occur at two all-electric, low-income housing communities located in different California climate zones The project will test and demonstrate the AWHC with at least twenty-five heat pump water heaters split between the two demonstration sites. The project will also test and demonstrate the ASCC with at least two space conditioning heat pumps, where the two housing units will be selected from the group participating in the AWHC demonstration.

As part of the CEC EPIC project, there are six technical tasks specific to this project:

1. Market Characterization
2. Develop Advanced Water Heating Controls
3. Develop Advanced Space Conditioning Controls
4. Test and Demonstrate Advanced Water Heating Controls
5. Further Research in Advanced Space Conditioning Controls
6. Market Barriers and Commercialization Assessment.



Project Data Model Framework

The overall project is designed to evaluate load flexibility technologies' ability to successfully shift, shed, shape, and shimmy demand of advanced, high-efficiency heat pumps for space conditioning or water heating in response to grid needs, building owner/occupant preferences, utility pricing, and DER availability. The project team will demonstrate the ability to automate and optimize the shifting of space conditioning or water heating heat pump load out of the evening ramp—particularly in the Spring and

Fall when the ramps are steepest—or away from times when the generation mix is producing the highest level of GHG emissions. The field testing will demonstrate heat pump operational flexibility, combined with other technologies and strategies (e.g., demand response, DERs such as advanced on-site storage, etc.), to provide grid support under current and future generation.

The project is funded under the EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

Collaboration

The EM&T program is co-funding the project through a Letter of Commitment for the CEC EPIC contract that is led by the UC Davis's Western Cooling Efficiency Center (WCEC) with other grant partners. While the EM&T program is co-funding the project through a contract with WCEC, SCE is also leveraging its access to CEC EPIC projects with learnings and best practices from other EPIC research activities. Also, as a founding member of WCEC, SCE has insights and access to ongoing research at UC Davis and leveraging that research to assist in this study and other efforts at SCE.

Results/Status

Field testing of the AHWC began in September 2024 at two sites in Woodland, CA, and San Jose, CA. The study includes twenty-four HPWHs and will continue through June of 2025. Testing follows a rapid M&V approach, with each HPWH alternating between AHWC and baseline control every three days—up to twice per week. The switching schedule is randomized to ensure an even distribution of baseline and AHWC days across the week, minimizing behavior-related bias in the collected data.

Below are highlights of AWHC successes and learnings:

1. Successfully scaling from a single lab unit to twenty-four HPWHs in the field.
2. Developed the processes to utilize the OEM's existing demand response platform to provide near real-time control of the HPWHs, with 5-minute update intervals.
3. Demonstrated successful use of the AWHC to proactively maintain user comfort, compared to the baseline control schema.
4. Every five minutes, the control optimizes for cost and GHG emissions based on household energy use patterns, which offers a more personalized

experience comparted to traditional price control.

Field deployment of the ASCC was originally planned for Q4 2024 but has been delayed due to challenges integrating smart thermostats into the Data Model Framework. The team plans to evaluate available options in early Q1 2025, aiming to initiate ASCC field testing within the same quarter.

Baseline interviews on water heating and space conditioning have been completed. The next round of interviews will take place during Q1 2025 for the AWHC and in late Q1 / early Q2 2025 for the ASCC.

Next Steps

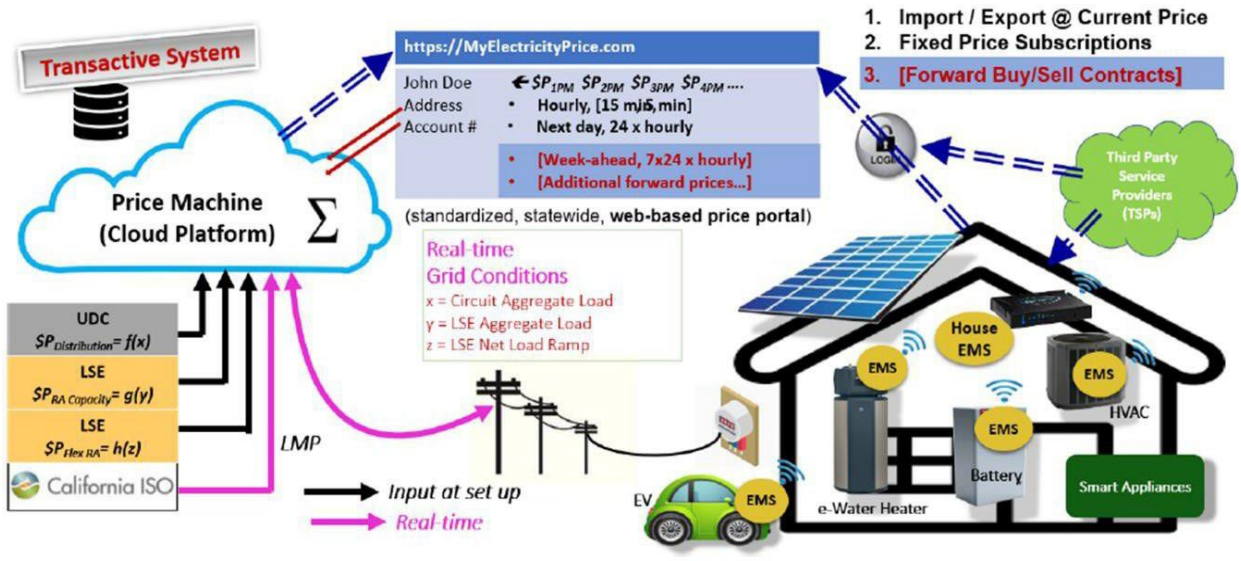
The project is ongoing and is set to conclude in June 2025. AHWC field testing will continue, with load flexibility performance evaluated through M&V data analysis and interview responses. In Q1 2025, the team will address the smart thermostat integration issue and initiate the ASCC field test.

In Q2 2025, UC Davis WCEC will continue collaborating with SCE on technology transfer, information dissemination, and engagement with flexibility stakeholders. The project team will also be developing a final report of compiled findings, lessons learned, and recommendations at that time.

DR21.03 Dynamic Rate Pilot

Overview

In response to Gov. Newsom's emergency proclamation to "ensure the reliability of electrical service during extreme weather events," the California Public Utility Commission (CPUC) authorized SCE to demonstrate how the RATES/UNIDE framework proposed by TeMix can help meet reliability needs for the summers of 2023 and 2024. The demonstration was approved by the CPUC in D.21-12-015 and is designed to "conduct comprehensive studies that fully assess the costs and benefits of real-time rates, including the required infrastructure, manufacturer interest, and customer impacts." The Pilot combines real-time pricing design and transactional subscription elements from both the RATES and UNIDE tariff concepts. The Pilot also investigates how customer based distributed energy resources can act as both flexible assets and grid interactive resources when these new pricing signals are transmitted to end use customers as proposed in the UNIDE model.

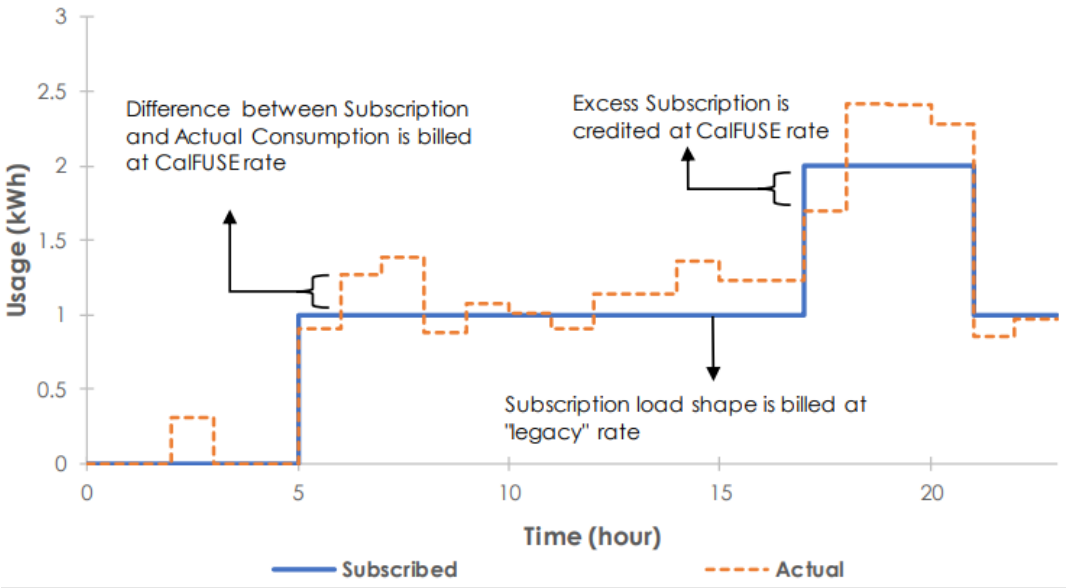


CalFUSE Concept for Dynamic Rate Design

The key operational tasks of the Pilot are to automate the creation of dynamic prices for the generation and delivery components of a transactive tariff and present these composite dynamic hourly prices via an internet-based secure pathway to be accessed by retail customers, wholesale market participants, and automated services platforms for distributed energy resources (DERs). Customers and their end use devices would be connected to the TeMix cloud platform to receive price tenders either directly, via local management, or from aggregated management signals from third-party automated services platform clouds via Internet/Wi-Fi/LTE to the secure receivers at the customer site. The decision instructs SCE to administer this demonstration under SCE's EM&T program.

SCE was encouraged to enroll residential, commercial, and industrial customers in this exciting demonstration. SCE works through reputable Automation Service Providers (ASPs) with existing relationships with these customer types and previously installed automation software or hardware at these customers' dwellings to streamline customers' involvement. This demonstration in 2022 was then modified to align with the CPUC's CalFUSE concept that brings more definition and functional scope to the original UNIDE framework as proposed in the Reliability Proceeding.

Under the CalFUSE design, each customer is provided with a tailored subscription for their monthly electricity use based on an analysis of their historical usage. During the pilot, the customer receives highly dynamic energy rates via their ASP that reflect grid conditions and will be able to make either buy or sell transaction leveraging this subscription to better match their operational needs against the needs of the local grid conditions.



Example of the Subscription as Hedging Product

The Pilot combines real-time pricing design and transactional subscription elements from the CalFUSE tariff architecture. For the CalFUSE hypothesis to be fully examined, the Pilot metrics are structured to develop a series of empirical analyses to assess the costs and benefits of real-time dynamic rate communications, with the ultimate objectives of transferring the research investments from the earlier CEC EPIC studies under GFO15-311 into flexible customer demand side opportunities that can accelerate solutions for system reliability for the summers of 2023 and 2024.

The project was co-funded under the EM&T Technology Assessments and Technology Transfer investment categories, as elements of both research goals are in this study. The Technology Assessments category assesses and reviews the

performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities. The Technology Transfer category advances DR-enabling technologies to the next step in the adoption process by raising awareness, developing capabilities, and informing stakeholders during the initial stages of emerging technology development for potential DR program and product offerings.

Collaboration

To implement the Pilot, SCE has executed a service contract with TeMix as the price platform software service. The platform transmits dynamic tariff prices securely to participating SCE retail customers during the Pilot and records these dynamic pricing tender transactions for settlement purposes via a "shadow bill" approach. The ASPs integrate with the TeMix platform on behalf of their customers.

SCE is working with other stakeholders such as major electric vehicle (EV) manufacturers and/or smart charger service providers, solar/battery aggregators or service providers, and others with the capability to directly receive dynamic price tenders from TeMix and optimize (on behalf of the customer) end use flexibility strategies (such as EV and storage charge and discharge schedules). TeMix provides optimization agents for vendors to assess their applicability for eligibility, security, and compatibility with current APIs (reducing the need for software development).

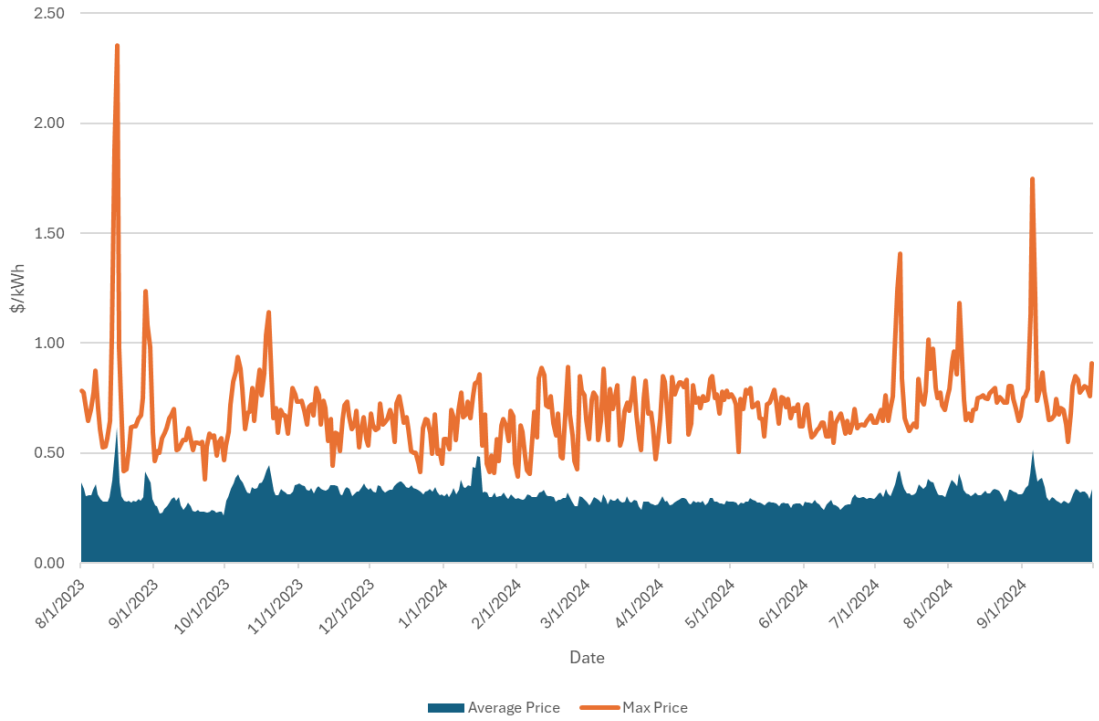
In addition, there are other technology and software providers who already manage groups of SCE customers for demand management services and other value streams. These providers and other ASPs are engaged and included in the project team as providers and advisors. SCE has established a technical advisory committee of industry experts and parties interested in the tariff design and transactive energy model of the CalFUSE concept to provide a communication platform for technology transfer as well as feedback for expert review of the Pilot activities.

Results/Status

During 2024, TeMix transmitted day-ahead hourly dynamic prices to three ASPs to help them manage the participants' hourly pricing transactions and optimize their electrical costs. Thirty-eight Pilot participants were active at various stages during this time, which included a mix of residential and commercial customers. TeMix provided shadow bills for customers monthly, which were then verified by SCE's billing department. Customer credits were determined by the difference between the shadow bill and the customer's otherwise applicable tariff (OAT).

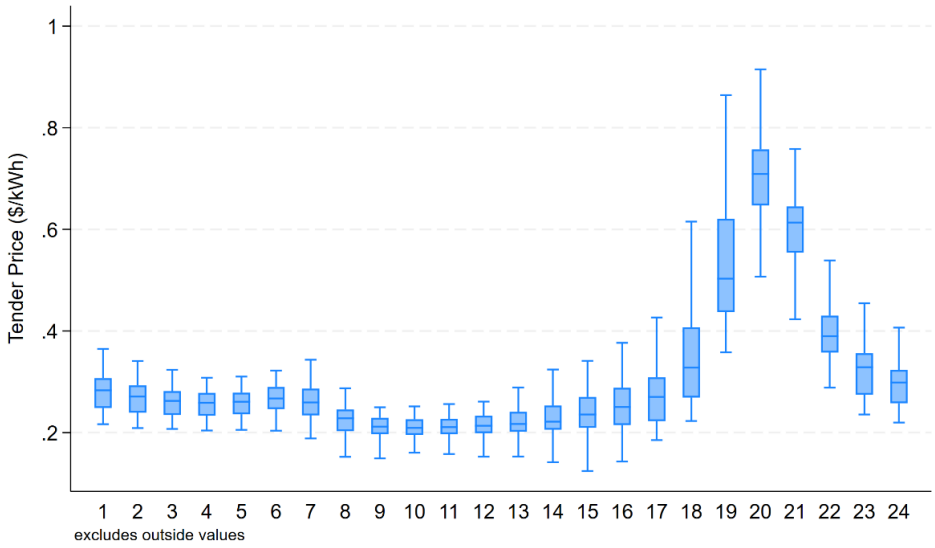
To demonstrate the variability of the dynamic hourly electricity prices that were communicated to customers, the figure below shows daily detail on the all-hours average and maximum tender prices. Price levels were less volatile from November

2023 through June 2024, with some higher-priced days appearing later in the summer of 2024 that reflect the higher costs of energy and local capacity.



Residential Customer: Average and Maximum Tender Prices

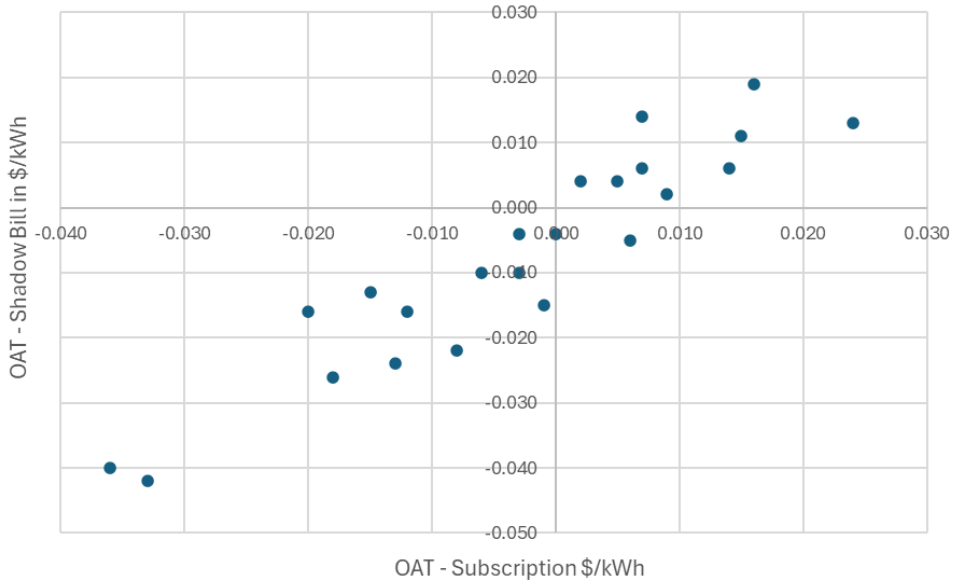
The box and whisker plot shows the intra-hour variability of hourly electricity prices across the day, with the highest prices still tending to occur during TOU on-peak hours (4 - 8 pm, hours 17 – 20).



Residential Customer: Summer Hourly Price Distributions

The benefits and/or impacts of the dynamic rates compared to the customer's historical subscription is being analyzed in the TeMix's detailed summaries and rate

comparison reports to the customer's OAT. Shadow bill credit calculation is affected by the relationship between the customer's average OAT price and their subscription price. The research team observed a correlation between the two data series at 0.936, indicating a very strong relationship between the shadow bill credit and the relationship between the OAT and subscription prices.



OAT – Shadow Bill vs. OAT – Subscription Price ($/kWh)

Next Steps

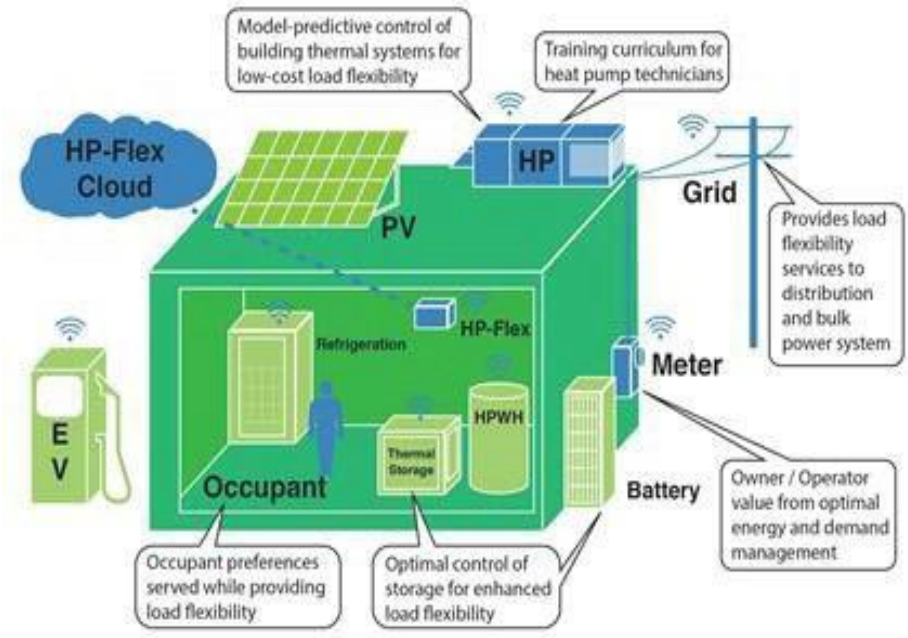
The Pilot's dynamic pricing platform ceased transmitting hourly prices to the automation service providers as of December 31, 2024. The project team will focus on compiling analysis of customer bill savings and load impacts through a measurement and verification process. Once analysis is complete for the 12-month period of data collection, customers will be credited for savings they would have realized under this dynamic pricing rate, and they will not be billed for more if the OAT bills are lower than the Pilot bills.

Final report deliverables will include evaluations of cost recovery, implementor interviews, experiential learnings, and recommendations for future investigation. The project team will deliver a final report no later than March 1, 2025, in accordance with the CPUC decision authorizing the Pilot.

DR22.02 HP-Flex: Next Generation Heat Pump Load Flexibility DR

Overview

Lawrence Berkeley National Laboratory (LBNL) submitted a proposal to the CEC in response to Electric Program Investment Charge (EPIC) solicitation GFO-19-301, Group 4. The proposal was awarded a contract agreement (EPC-19-013) by the CEC for a $3,000,000 grant to fund the development and field site evaluation of an open-source, scalable, low-cost control flexible heat pump solution (HP-Flex) for optimal demand management of high-efficiency heat pumps in small and medium commercial buildings. Southern California Edison (SCE) provided a Letter of Commitment in support of LBNL's proposal, with a proposed cost share of $300,000 ($150,000 / $150,000 from EE & DR emerging tech funds).



HP-Flex: Next Generation Heat Pump Load Flexibility

The goal of the project is to develop open-source control algorithms and educational curricula to train the next generation of engineers and technicians, to help promote the large-scale deployment of replicable, demand-flexible heat pump installations in small to medium-sized commercial buildings, and to increase benefits to both individual building owners and the distribution grid by enhancing heat pump demand flexibility. This system will minimize energy use while allowing buildings to effectively participate in flexible DR programs and dynamic pricing tariffs, to provide reliable and cost-effective load flexibility to the grid.

The project objectives are:

- Develop an advanced, integrated, open-source control system to cost-effectively provide energy optimization and load flexibility to heat pumps in small and medium commercial buildings.
- Verify that flexible heat pumps can meet the following criteria:
    1) Achieve a 20% reduction in site peak energy costs compared to a traditional heat pump with scheduled thermostatic control.
    2) Provide 50% load shed during summer or winter peak-load events.
    3) Provide 20 kWh of daily load shift capacity for a typical commercial building during the shoulder seasons.
    4) Provide "shimmy" services equivalent to 10% continuous response of average baseline load.
    5) Enable 25% of the baseline load to respond to dynamic prices to shape daily load profile in summer and winter.
    6) Meet a financial payback period of 2 years.
- Integrate and control a thermal energy storage system with a heat pump optimized with HP-Flex.
- Develop educational curricula to train engineers and technicians on the design, installation, and maintenance of load-flexible heat pump systems.

The project was funded under the EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

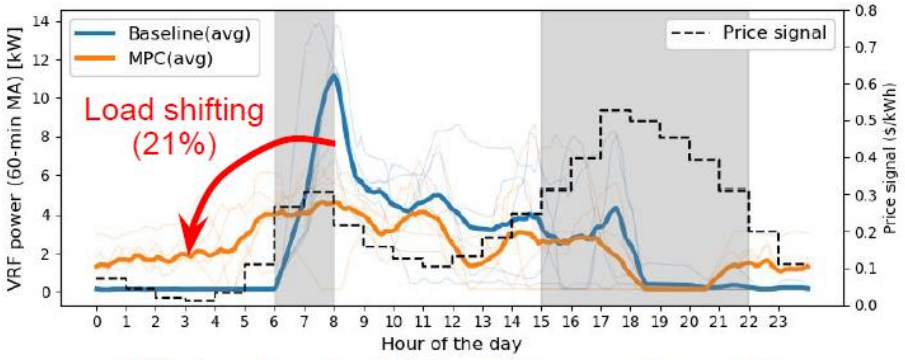
Collaboration

The project is being co-funded by the SCE Emerging Markets and Technologies and Emerging Technologies Program and is supplementary to work at LBNL funded by the CEC Electric Program Investment Charge (EPIC). SCE is working with LBNL as a co-funding partner and active reviewer of the work in progress. SCE engages other industry stakeholders and subject matter experts that serve on the Technical Advisory Committee (TAC) establishing direction for the research team and to ensure that SCE is receiving the learnings from the project that are most valuable to its customers.

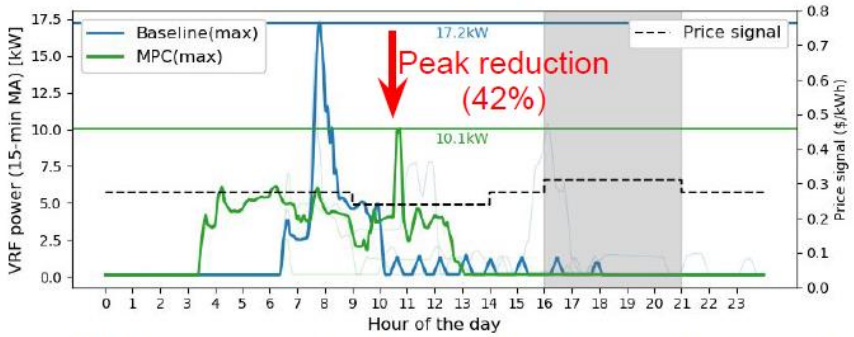
Results/Status

LBNL has finalized the M&V plan for all six field test sites and began implementation. In a Q3 presentation, LBNL provided the following updates as initial data findings.

1. UC Davis Western Cooling Efficiency Center
   - Existing HP: 15-ton VRF with Heat Recovery serving offices and one lab
   - Load shifting results of 21% Winter / 26% Summer with the load shifting dynamic rate strategy
   - Peak reduction results of 42% Winter / 44% Summer with the cost reduction TOU + demand charge strategy

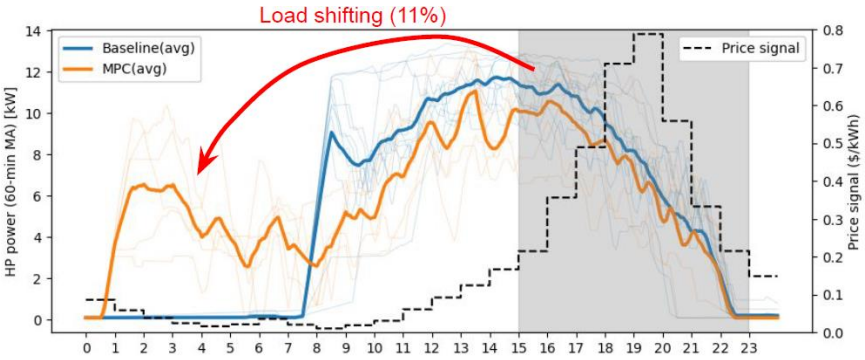


Winter load shifting (dynamic rate)



Winter cost reduction (TOU+demand charge)

2. Public Library, Los Angeles County
   - New installation of 20-ton and 5-ton heat pump RTU
   - 11% summer load shifting results, despite tight 70-72F deadband, all-day cooling load characteristics, and limited to two units for conditioning control.



Summer load shifting

3. College Site in Bakersfield
    - Two new 7-ton HP RTUs installed; testing is underway.

4. Non-Profit Center, San Bernardino
    - HP already installed. Team has configured the Savant gateway installed hardware and connected thermostats in mid-August.
    - Additional hardware is pending install for remote access.

5. Community Church, San Leandro
    - Recent furloughs have slowed progress.
    - Pending notice-to-proceed and a date for installation.

6. Community Church, Menlo Park
    - Same status as San Leandro Community Church (both sites are being processed together).

Additional results were made available in a draft Baseline Characterization Report that was provided to the SCE project team and is under review. LBNL made significant progress on Workforce Development and information dissemination activities including several peer-reviewed papers, presentations, conferences, and workshops during Q3 – Q4 2024.

Next Steps

LBNL and SCE will continue to coordinate on updating the project timeline as well as reviewing and finalizing interim testing results and deliverables. As the newer sites complete installation, the project team will focus on verifying installation setup for full testing and compiling the preliminary findings.

DR23.01 DR-TTC Dynamic HVAC Test Chamber

Overview

SCE Technology Test Center (TTC)

The SCE's Technology Test Center (TTC) evaluates a variety of technologies in controlled environments that mirror real-world conditions and customer experiences. This generates comprehensive performance data and innovative test methods which are used by SCE customers, policymakers, and utility programs to make informed decisions regarding the investment and application of cleaner technologies.

The TTC is pursuing a major renovation project to the facility layout and pursuing updates to its testing capabilities. Dynamic testing or load-based testing is necessary to better characterize the performance of actual advanced controls of various heat pump systems.

Current TTC HVAC lab test capabilities are limited to steady state methods that disable native HVAC controls. A dynamic test method in the lab produces metrics/results that include the operation of native controls.

It is important to assess test methods that can provide ratings representative of field performance when equipment is operated under its own controls and under loads that vary with ambient temperature. Additionally, the test chamber can also be used to test other small commercial self-contained refrigeration equipment.

Project objectives are:

- Construct an environmental test chamber capable of advanced dynamic HVAC testing.
- Demonstrate a dynamic test and generate sample test data.

- Identify and prioritize near-term potential test projects, which may include but is not limited to: the Advanced Heat Pump Coalition's Heat Pump Rating Representativeness Validation Project, LBNL CEC projects to supplement laboratory testing, F-Gas Reduction Incentive Program (FRIP), and parallel EPRI laboratory testing.

The project is co-funded under the EM&T Technology Assessments and Technology Transfer investment categories, as there are elements of both research goals in this study. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

The Technology Transfer category advances DR-enabling technologies to the next step in the adoption process by raising awareness, developing capabilities, and informing stakeholders in initial stages of emerging technology development for potential DR program and product offerings.

Collaboration

The project is being co-funded by the SCE Technology Test Centers, the SCE Emerging Technologies program, and the SCE Codes and Standards program. The completion of this test chamber will enable a wide variety of future project partnerships to support programs/activities such as the California Statewide Electric Emerging Technologies Program, Building Electrification, Codes and Standards, CEC EPIC, CARB - FRIP, and CalFlexHub.

Results/Status

The vendor has successfully completed all design-phase coordination and activities in Q3 – Q4 2024. During Q3, the design contractor presented a high-level comparative analysis for one of the key design considerations: refrigerant options for the mechanical systems that will serve the dynamic environmental control chambers.

An overview was given for the options of R-449a, R-454c, and R-744 (CO_2), which are the most feasible at the time of design. R-449a is considered to meet the performance requirements as the best balance of key design considerations (e.g. energy efficiency, GWP, maintenance/constructability impacts, safety, install costs).

In Q4, the design vendor successfully conducted a site visit to finalize the necessary documentation details, measurements, and scanning of current test chamber areas/supporting infrastructure.

All design deliverables proposals were provided and accepted in Q4 2024. These design deliverables now provide a strong foundation for updating the Technology Test Chamber lab test capabilities to more advanced, dynamic, load-based

environmental chamber testing (i.e. guided by CSA EXP07:19). Updates are tentatively sought for two unique chambers: one in a single-room configuration, and another in a dual-room configuration of both indoor/outdoor environments.

Next Steps

The project team will initiate a competitive RFP and award for executing the final project construction phases to complete the lab test chamber project. Projected completion is expected by Q1 – Q2 of 2026.

DR23.03 Achieving Integrated and Equitable Decarbonized Loads with the CalFlexHub

Overview

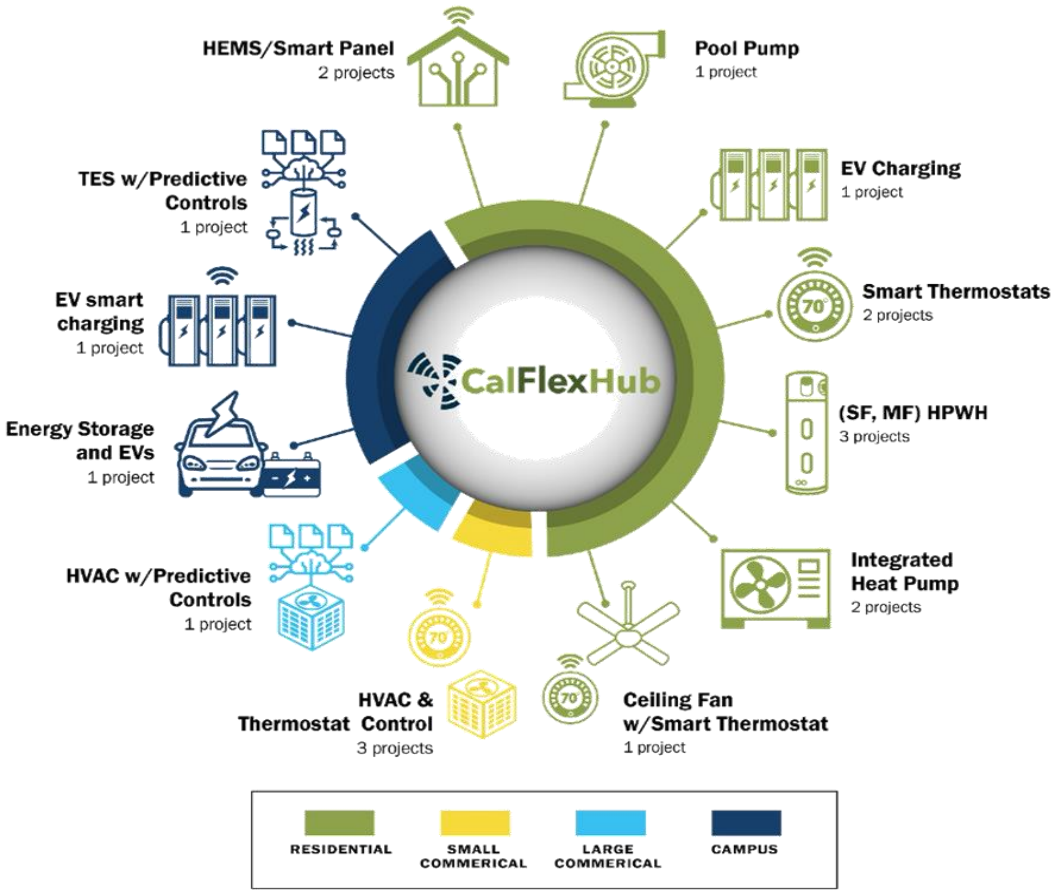
Lawrence Berkeley National Laboratory (LBNL) submitted a proposal to the California Energy Commission (CEC) in response to Electric Program Investment Charge (EPIC) solicitation GFO-19-309. The proposal was awarded a contract agreement (EPC-19-309) for a $16,000,000 grant to fund the California Load Flexibility and Deployment Hub. Known in short as the CalFlexHub, its goal is to accelerate the understanding of how customer electrical end-use loads could provide dynamic load flexibility. CalFlexHub will achieve this understanding by demonstrating the technologies and incentives needed to provide that flexibility, and then increasing knowledge and understanding of specific customer needs through field research and customer surveys.

The EM&T program provided a Letter of Commitment (LOC) in support of LBNL's proposal for the EPIC GFO 19-309 solicitation. As stated in the LOC, SCE's participation in this project includes technical advisory support, active peer review of LBNL's applied research and development (ARD) activities during the project schedule, and match funding of $600,000 to provide supplemental funding for SCE-specific projects in SCE territory or in SCE facilities.

In addition to the cash commitment of approximately $150,000 per year for four years, SCE is also including its Energy Education Centers (EECs) and its Technology Test Centers (TTCs) as training and workshop resources (based on availability) for CalFlexHub interactive displays and exhibits, technical consultations, classes, seminars, and test beds to conduct small-scale testing in SCE laboratory settings.

The CalFlexHub program at LBNL will develop, demonstrate, and evaluate complementary technology platforms to actuate flexible loads using technology compatible with the CEC's Load Management Standards (LMS) platform, which will be used to communicate the prices, grid signals, and greenhouse gas (GHG) emissions signals.

The LBNL team will pilot test and demonstrate innovative technologies compatible with the LMS platform to enable affordable flexible loads. Once technologies are pilot tested and usability research is complete, CalFlexHub will support commercialization of load flexible (LF) technologies that are proven to be usable and effective through completed field research.



CalFlexHub Overall Project Portfolio

LBNL intends to achieve the CEC's goals with a focus on the following objectives:

- Identify, develop, evaluate, demonstrate, and deploy cost-effective, scalable, load-flexible technologies that are consistent with building energy efficiency, appliance, and load management standards, to provide continuous load shaping from dynamic prices and GHG signal response.
- Create a portfolio of technology projects across various building types and sizes including single family residential, multi-family, commercial buildings, and integrated campuses. Evaluate the performance of integrated control and optimization of these technologies to reduce customer bills and GHG emissions.
    - These technologies include building electric end-uses and other DERS such as PV, thermal and electric storage, and EVs.
- Deploy LF technologies to demonstrate the ability for electric customers to receive the LMS price and marginal GHG signals at five-minute increments and report statistically significant effects. Demonstrate that load-responsive technologies can receive and respond to signals via open, secure protocols.

- Identify ways to improve usability of technology solutions to increase customer benefits. During deployment, score the usability of each LF technology on a statistically supportable sample of customers using the System Usability Scale (SUS) and collect input from customers and end users to develop strategies to improve device usability and customer engagement strategies.
- With an Equity First strategy in CalFlexHub, evaluate and demonstrate key technologies for disadvantaged and vulnerable communities to overcome financial and health burdens, and develop plans to build scalability through innovation and targeted deployment of those technologies.
- Develop a database of key performance metrics, including the usability for flexible technology and strategy pathways and generate these metrics for 2025, 2030, and 2040 scenarios. Publish summaries as part of the annual report for CalFlexHub stakeholders. Evaluate how these technologies perform in the CalFlexHub field tests.
- Develop and deploy the CalFlexHub Solutions Center website and a clearinghouse to disseminate information, technology reports, and case studies to report on "what works," sharing California and national RDD&D. Create a sustainable partner engagement platform and stakeholder engagement ecosystem and develop a Technology Transfer Best Practices Manual for CalFlexHub Innovators.

SCE will work with the LBNL team on the scope of individual activities that are specific to SCE's strategic load management interests. While SCE is included in the project's Technical Advisory Committee (TAC) meetings as part of their role in the project along with other qualified professionals in accordance with the CEC's contract with LBNL (EPC 19-309 Agreement), SCE will also actively facilitate a dynamic "real time" technology information transfer of the knowledge gained, experimental results, and lessons learned from the project.

SCE will receive early-stage drafts of any project related documents and deliverables, specifically those documents that will help SCE bring these technologies into their program offerings. Specifically, SCE will receive the following during the execution of the project:

1. Copies of the monthly progress reports submitted to the project's Commission Agreement Manager (CAM), per EPC 19-309, Task 1.5
2. Drafts and final copies of reports as specified in the SCE Specific Deliverables
3. Meetings and online seminar updates as specified

SCE will also receive periodic project updates, preliminary findings, and completion meetings, via online seminar in accordance with a schedule mutually agreed

between the LBNL project team and SCE to support the technology transfer of project activities for SCE's internal stakeholders.

SCE is interested in identifying "off the shelf" measures in the Technology Demonstration and Deployment (TDD) projects. The research performed by the CalFlexHub in the TDD stage should focus on technologies with a current technology readiness level (TRL) between 6 and 8. TRL 6 is used as the level required for technology insertion into system design and normally the last stage where technology has been demonstrated in the engineering/pilot scale in the relevant environment.

An additional goal of CalFlexHub is to move these technologies up one or more readiness levels by the end of the project. TRL 8 is the actual system being operational and qualified through demonstration, wherein the technology has been proven to work in its final form and under expected conditions. SCE engineering staff will assist with the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable the operating system's design.

The project is funded under the EM&T Market Assessments and Technology Assessment investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

Collaboration

SCE is working with the LBNL CalFlexHub research team, with SCE staff acting as advisors and active reviewers of the work in progress. To facilitate enhanced knowledge transfer, key members of SCE's project team will collaborate with LBNL engineering staff and researchers to provide insight into and influence over each project's initial design and direction throughout its duration.

SCE engages other industry stakeholders and subject matter experts to serve on the Technical Advisory Committee (TAC) establishing direction for the research team and to ensure that SCE is receiving the learnings from the project that are most valuable to its customers. In addition to the TAC meetings, SCE will receive more timely updates for ongoing consultation and access the reports and deliverables produced for the CEC contract advisors.

Results/Status

Monthly CalFlexHub check-in meetings were conducted throughout the third & fourth quarters of 2024 and SCE was provided with materials supporting the project deliverables as per the master agreement task order.

- Kick-off presentation with summary overview of the CalFlexHub overall project, its goals, and specific tasks planned for research.
- Project Abstracts Summary Document was provided, with proposed Research Area Topics outlining key sub-projects for focused engagement with SCE.
- Six selected projects specific to the SCE collaboration effort have continued during Q3 and Q4 of 2024. LBNL continues to coordinate on progress of each of the projects. These projects include the following:

Project #1: Elexity Model Predictive Control

The project team worked with the AI developer partner to successfully recruit two customer test sites. The project team and AI partner also successfully developed a work plan detailing relevant site information, testing period, response strategy, and timeline. Both test sites are primarily conditioned with Heat Pumps and will be tested in heating and cooling mode for load flexibility.

The AI partner successfully connected to the 2-week continuously hourly varying price signals hosted on MIDAS server and is getting ready to test with CalFlexHub price signals. This effort will model an hourly price responsive load flexibility response and simulate future dynamic pricing AI elasticity.

This project will be a key test of commercial HVAC-oriented load shifting and is expected to involve extensive daily energy shifting. Customer acceptance will be analyzed through logs of relevant HVAC control actions (e.g. customer-originated overrides triggered by occupants and by program administrators).

Project #2: Heat Pump Water Heaters Training Center Support/Demo

LBNL and SCE coordinated to create plans for potential HPWH training curriculum and associated materials development. Training opportunities are intended to:

1) Enable a hands-on course for contractors pitching the technology directly to consumers and installing the technology
    a. LBNL created materials that could be presented as either flyers or handouts, designed for hands-on training with contractors. High-level content covers 1) how a business can benefit from offering this service, 2) why customers would request this service, 3) how to identify appropriate sites, 4) required hardware, 5) HPWH fundamentals. More detailed content describes the process of installing a Wi-Fi communication module into HPWHs from various manufacturers and configuring the module to receive signals from the cloud.

2) Explore a web-based approach for architects, engineers, and Title 24 consultants specifying the equipment in their designs.
3) LBNL drafted slides for presentation materials targeting designers, engineers, and Title 24 consultants. LBNL has also composed a draft presentation script and is now revising that script based on feedback from SCE staff.

Project #3: Gateway with Universal Devices Inc. (UDI)

UDI has completed its research on developing a home demand flexibility gateway, and successfully demonstrated pricing signal integration via OpenADR 3.0, cellular data connection, and functional control of an initial set of common devices. UDI drafted a memo summary report, detailing the findings. The report is receiving peer review and information dissemination activities are underway. Findings have been shared to support the revision of OpenADR 3.0 standard.

Project #4: Identifying Target Markets and Key Drivers to Encourage Market Adoption of Thermal Energy Storage

LBNL finished draft content covering the market analysis portion of this project. The draft content includes evaluation of the political, economic, social, technical, and legal environments impacting the model for TES. Additionally, it includes an evaluation of the various companies and technologies currently on the market, creating an understanding of the baseline technologies and reasons for limited adoption. LBNL also developed a simulation modeling plan to keep the simulation study focused/on target, which includes:

1) the research questions for investigation
2) the study methodology for addressing them
3) the system designs to simulate.

LBNL completed the top-down analysis based on the LBNL-LOAD model. Analysis identified that for building types with the most cooling demand, large commercial buildings typically represented 10 - 28% of the load. The cooling load of small-medium commercial buildings is often 2-3x that of large commercial, indicating more total potential if deploying TES in small-medium commercial buildings.

Project #5: Price-response Business Models

LBNL: (1) Developed the Task 2.1 Stakeholder Needs Assessment interview material; (2) Met with the business models lead from the Department of Energy to compare approaches and discuss findings from that effort; and (3) Reviewed the secondary source materials compiled to support California load flexibility policy efforts (i.e., CPUC Rulemakings R2011003 and R2207005, CEC Load Management Standards rulemaking, etc.). LBNL started building the business model taxonomy, with inputs from parties to CPUC rulemakings, interview data, etc.

LBNL has compiled existing materials from the CPUC docket to build an initial taxonomy of material, mapped to materials from existing Task 2 work. A December meeting was held with SCE to go over the materials and discuss interview needs.

Project #6: EV Charging Collaboration

LBNL has engaged one partner, an awardee from the CEC grant solicitation: Responsive, Easy Charging Products with Dynamic Signals (REDWDS). LBNL is working on a refined scope of work and load impact CFH investigation that is complementary and differentiated from the CEC REDWDS grant activities. Contracting is underway. The CFH EV charging collaboration will set out to:

1) Create critical knowledge through large-scale demonstration of dynamic pricing-based EV smart charging to help EV aggregation & optimization providers be ready for enrolling customers into dynamic rates.
2) Characterize EV charging and bidirectional charging emerging technologies found in REDWDS projects and contrast pros and cons of communicating grid signals through telematics vs EVSE.

Next Steps

LBNL and SCE will continue monthly coordination and proceed with work on the six sub-project scopes throughout 2025. Deliverables including preliminary data reporting, progress/completion meetings, and Technical Advisory Committee updates are ongoing.

Project #1: Elexity Model Predictive Control

The project team plans to conduct testing using the 2-week continuously hourly varying price signals for both sites in Q1 – Q2 2025.

Project #2: Heat Pump Water Heaters Training Center Support/Demo

Next steps are to finalize the training script and record webinar information. The course logistics will be in development and align with site availability.

Project #3: Gateway with Universal Devices

The project final report will continue undergoing peer review and additional information dissemination activities are underway.

Project #4: Identifying Target Markets and Key Drivers to Encourage Market Adoption of Thermal Energy Storage

LBNL will explore the potential of deploying TES in small-medium commercial buildings. The team will move on to the simulation tasks evaluating suitability of TES technologies for the identified commercial building segments.

Project #5: Price-response Business Models

LBNL will finalize the parameters and timeline on the second phase of tasks with feedback from SCE.

Project #6: EV Charging Collaboration

The project team will identify the data criteria necessary for analysis and finalize the approach for engagement with the REDWDs partner and price machine provider.

The broader CalFlexHub Project at Lawrence Berkeley National Lab along with SCE advisory and project participation is scheduled to continue through the end of 2025 in accordance with the terms of the CEC EPIC contract.

DR24.01 Behind the Meter Optimization of Load Technologies (BOLT) Study

Overview

In 2024, the EM&T program has developed the Behind the Meter Optimization of Load Technologies (BOLT) study to explore innovative DR system approaches to capture a wide range of residential consumer technologies, such as emerging" smart house" end uses and appliances, to significantly enhance both customer benefits and grid performance.

This strategic assessment study will investigate emerging consumer technologies that have load management capabilities, including electric vehicles (EVs), behind-the-meter (BTM) batteries, heat pump water heaters (HPWHs), pool pumps, and other potentially flexible, dispatchable appliances and systems. The BOLT study will also design and test new incentive models that are specifically crafted to boost customer participation and performance of these advanced technologies in new models of demand response. By also conducting a field assessment of these cutting-edge technologies alongside attractive incentives, the BOLT study intends to demonstrate the efficacy of load management measures utilizing an innovative comprehensive operational model structured to manage a diverse load management end use portfolio.

Research questions for the study include the following:

Primary Design Issues:

- What are the demand reductions (for development of deemed savings) that can be delivered by various end uses, individually and as a bundle?
- What are the reductions per SCE customer and per device under different scenarios/planning conditions?
- How does the magnitude and duration of dispatchable demand vary as a function of controllable end uses, weather conditions, event start, and hours into the event?
- How do incentive levels, modes of communication, and intensity and channel of marketing influence participation rates?
- What end uses and devices are most cost-effective for participation?

Secondary Operational Factors:

- How many sites should SCE enroll in BOLT to ensure it can accurately estimate load impacts?
- What are the identifying characteristics of customers who enroll in BOLT?
- What is the current saturation and geographic location in SCE territory for specific types of connected devices applicable for BOLT?

- How large (connected kW) are the end use loads, and how coincident are their annualized load shapes with SCE and CAISO peak loads?
- What communication protocols are used by the connectable devices, and are they compatible to receive DR signals and dispatches?

A key research objective for the BOLT study is to investigate how SCE can enhance the customer experience through a unified program tariff for multiple load management technologies at one service location. This new model has the potential for simplifying the enrollment process, providing customers with seamless experience and clear insights into potential earnings from their participation in load management programs. It will allow customers to enroll multiple load management technologies under a single program, replacing the current system where different technologies require separate enrollment processes. This streamlined approach is poised to transform how customers interact with load management programs, making it easier and more rewarding to participate in reliability programs and demand flexibility.

The project is funded under the EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer markets for load management-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews the performance of load management-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

Collaboration

To implement the study, SCE will be working with internal teams and an external evaluation contractor to develop the study design, operations, M&V, and go-to-market strategy. The first phase of the study is to conduct residential customer surveys to assess the range of customer interest in different incentive structures, options for dispatch timing and durations, and availability of in-home technologies.

In addition, there are other technology and software providers who already manage groups of SCE customers for demand management services and other value streams. These providers and other automation service providers (ASPs) will be engaged to collaborate with SCE in assessing the technologies as they are integrated in the field.

SCE is continuing to engage other innovative partners interested in collaborating with the study. SCE expects that these partners can provide consulting and technical services in the areas of market and grid operations, licenses for automated service platforms, economic reviews, and system impact analyses (e.g., avoided cost calculations), and the estimation of load shift impacts and energy reduction savings.

Results/Status

With the research objectives now resolved, the project team has been interviewing vendors, developing systems integration strategies, and initiating the contracting process. Three vendors are engaged thus far, and SCE is actively working on onboarding a fourth. Analysis of vendor proposed budgets is complete and the next steps will be to finalize procurement terms and conditions and final contracting.

The design team has built a configuration approach for the BOLTs study internally that will facilitate enrollments, randomize group assignments, nominations, and manage event dispatching. The research team further assessed existing system capabilities and established a manual event dispatch strategy that circumvents the use and complexity of APIs.

With a contractor, the project team has identified the survey target population and conducted an internal survey dispatch demo test to team members. When the survey is launched, it will measure what smart device owners value most about a given product or service, to collect precise customer type profiles to make more informed DR offerings and assess pricing opportunities.

Next Steps

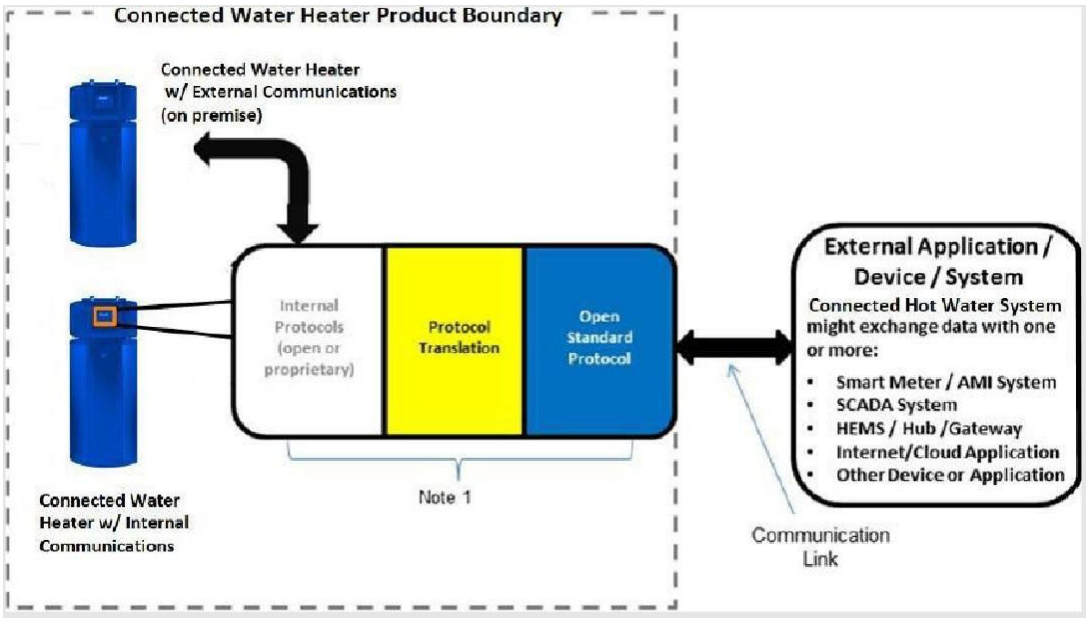
The SCE Project Team will work on establishing vendor connections and access to the event notification system. The study design team will be sharing pricing strategy with vendors and combine the prices from all three vendors to calculate an average. In parallel, the implementation team is working to finalize and update internal requirements to proceed with purchase order processing in collaboration with SCE supply management.

2. Projects Completed Q3 – Q4 2024

DR19.08 Grid Responsive Heat Pump Water Heater Study

Overview

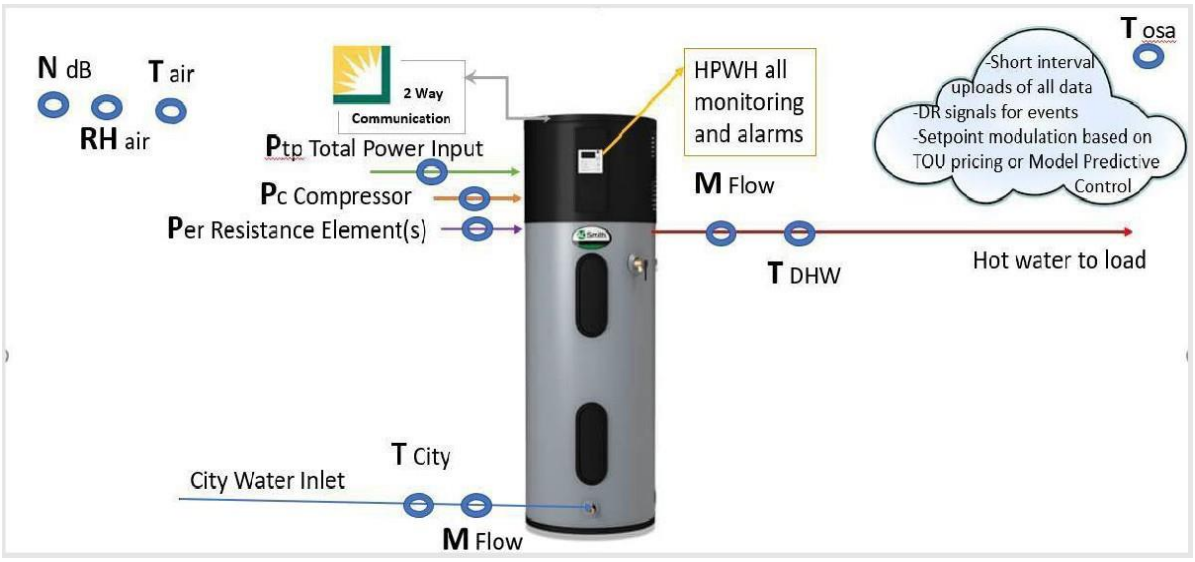
SCE's Emerging Technologies Program (ETP) and Emerging Markets and Technology (EM&T) Program have been conducting joint technology assessment studies of heat pump water heaters (HPWHs), and this study was a continuation of those efforts. The research team has been examining innovative emerging data management technologies that are applied and implemented for the deployment of the HPWH controls and their associated communication equipment, and for the test instrumentation and data collection of field studies when installed in customer homes.



Connected Water Heater Communications Architecture

As part of San Joaquin Valley (SJV) Disadvantaged Communities (DAC) Pilot Projects, SCE deployed electric HPWHs equipped with smart-grid communication technology that allowed these water heaters to be used as a grid-responsive technology element in the pilot to electrify homes and reduce emissions within the SJV and California City.

The EM&T portion of the project provided twelve (12) HPWHs with hardware and software to allow grid-responsive communication between the HPWH and the grid to control tank temperature and HPWH operation. The same twelve HPWHs received instrumentation to monitor, at a minimum, the performance of the water heater, signals between the grid and HPWH, operation of the HPWH, water flow and temperatures, local grid conditions, and ambient conditions.



Metering Diagram for HPWH Performance Testing

The EM&T study was designed to address the following research issues:

- Assist SCE in understanding integration of renewables and load dispatch as well as helping inform SCE if and how effectively a grid-responsive HPWH can provide flexible load control and hot water storage over various times. SCE hopes to gain insight into how heat pump water heaters acting as aggregated distributed resources can be used to benefit the grid and simultaneously offer residents the ability to manage energy consumption through time-of-use (TOU) management of their energy consumption.
- Inform how hot water storage over various times can be used to add load or shed load. The demonstration research will provide anecdotal results that should enhance SCE and other stakeholders' understanding of utilizing heat pumps for assisting in the integration of renewables and offering a resource for load dispatch. This will be achieved through detailed monitoring and analyzing the technical performance of HPWHs, including the technical capability of providing local grid impacts from grid responsive HPWHs and their performance in supplying hot water for the customers.
- In addition, the overall DAC project will gather information on customer experience, technical performance, grid benefits, and impacts of actual performance of the grid responsive HPWHs as electric appliances in underserved communities.

All twelve homes selected have a garage for the HPWH and no recirculation system. The twelve homes are part of a larger SCE pilot to electrify 150 homes and reduce emissions within the SJV. The prime General Contractor (GC) and Community Energy Navigator (CEN) of the larger project were responsible for customer selection and the selection and installation of the grid-controlled HPWH and a communication package to be used by SCE for the grid responsive signals.

The project was funded under the EM&T Technology Assessments and Technology Transfer investment categories, as elements of both research goals are in this study. The Technology Assessments category assesses and reviews performance of DR-enabling technologies through lab/field tests and demonstrations designed to verify or enable DR technical capabilities. The Technology Transfer category advances DR-enabling technologies to the next step in the adoption process by raising awareness, developing capabilities, and informing stakeholders during initial stages of emerging technology development for potential DR program and product offerings.

Collaboration

The research team consisted of SCE's Engineering Services group under the direction of the ETP and EM&T program managers and was assisted by SCE's technology consultants. The SCE Income Qualified Program group oversaw the SJV DAC and works with the research team to select the customers for the study.

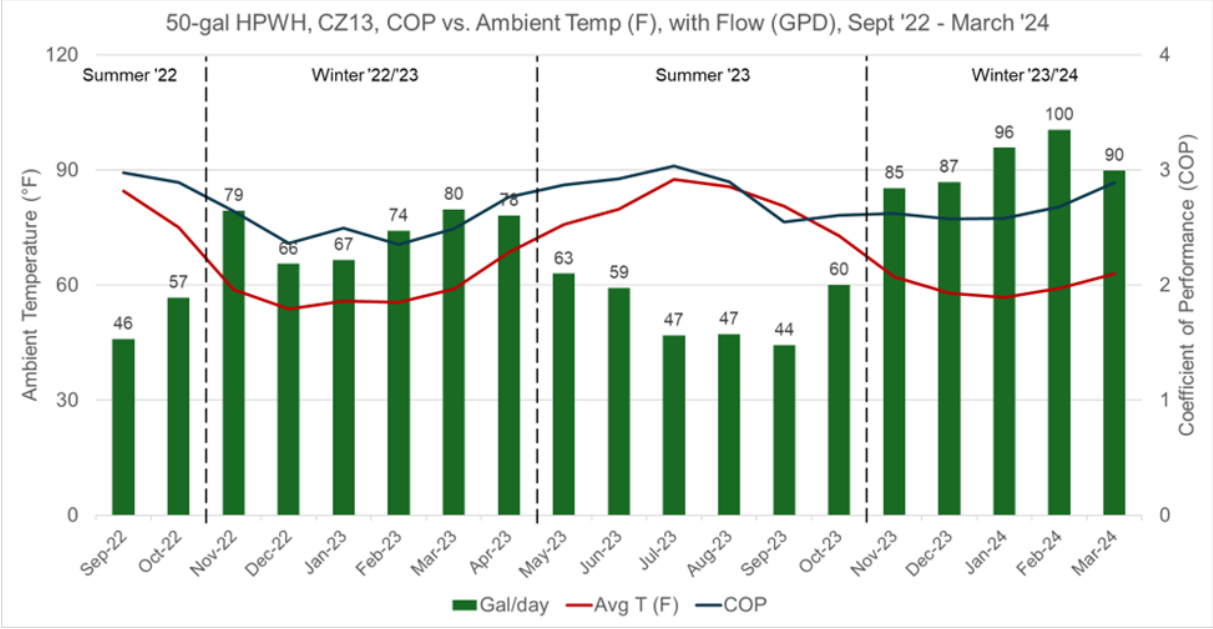
Community leaders from the San Joaquin Valley and the communities of California City, Ducor, and West Goshen are also involved. The project was jointly funded by the EE, DR, and the Energy Savings Assistance (ESA) and California Alternate Rates for Energy (CARE) programs.

Results/Status

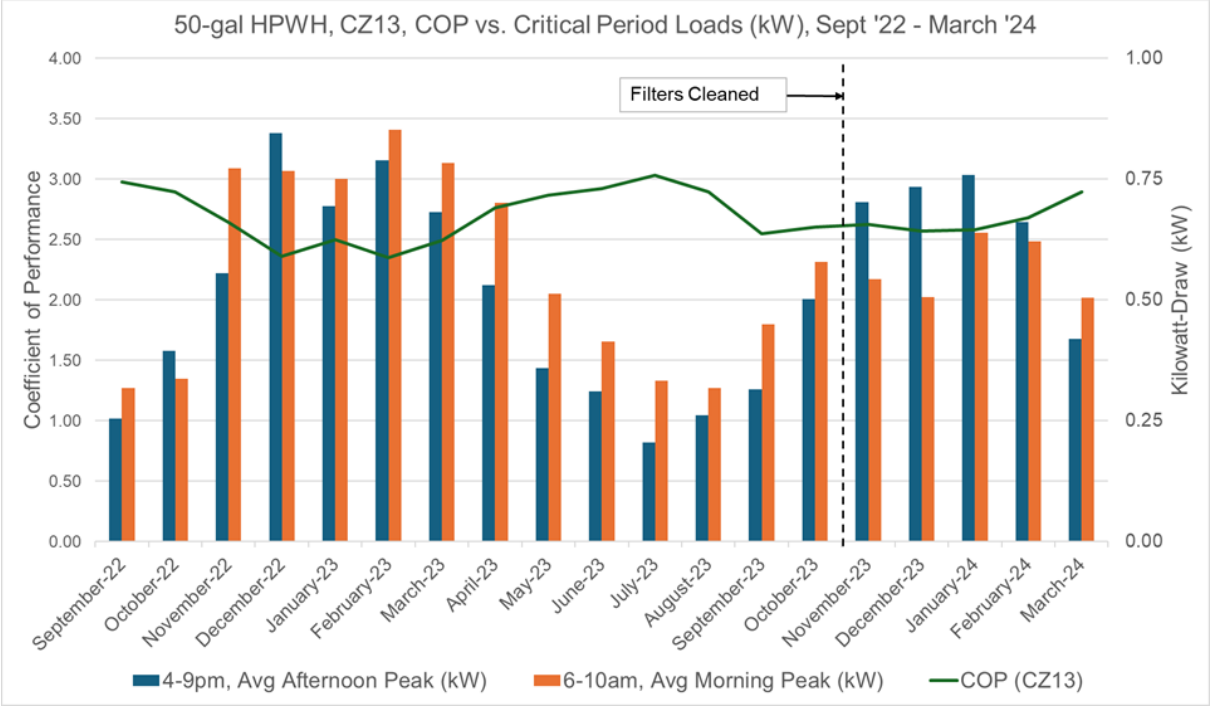
The field work, data monitoring, and analysis for the study has been completed.

Key observations include:

1) Wide variations in HPWH performance and hot water usage observed across all test sites.



50-gal HPWH COP vs. Ambient Temperature & Flow Rate over 18 Months



50-gal HPWH COP vs. Critical Period Loads over 18 Months

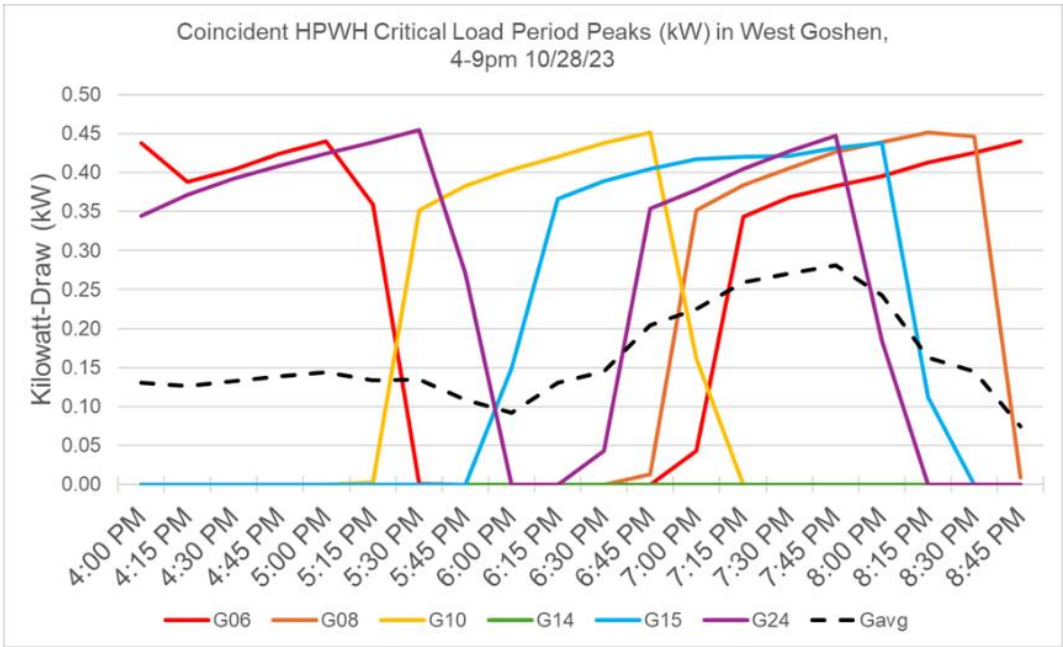
2) The potential for installation-related faults is non-trivial and can introduce significant inefficiencies/thermal performance impacts. Issues encountered included the following:
    a. seized mixing valve
    b. nearby clothes dryer improperly vented (added lint buildup)
    c. pipe/fittings materials selection induced higher corrosion than expected
    d. obstructed/inaccessible air filter
    e. obstructed airflow.

    Proper methods for quality installation and equipment sizing should be studied further.

3) Overlooked simple maintenance such as neglecting to clean filters can significantly negatively impact HPWH performance. Typical/proper practices in operation and maintenance should be studied further.

4) Hardware issues prevented thorough DR investigation, but limited study appears to indicate minimal impacts to user experience for ~19% of 4 – 9pm demand reduction; however, the demand levels per unit are considered low.

The project team also identified variability in the critical load peaks within the 4 – 9pm window that assisted in characterization of HPWH use. These research findings warranted the initiation of a follow-up project, to approach all customer sites for continued assessment of grid responsive HPWHs, with the SCE Codes and Standards team.



Summary of Coincident HPWH Critical Load Period Peaks

Next Steps

A draft report has been completed including baseline HPWH aspects of the project in Q4 2024 and is under peer review. Finalization is expected to be completed in Q1 – Q2 2025. The full report will be available in 2025 at www.dret-ca.com/wp-content/uploads/2025/4/DR19.08-Grid-Responsive-Heat-Pump-Water-Heater-Study.pdf.

DR23.02 Flick Power Study

Overview

SCE's ETP and EM&T Programs jointly initiated a field pilot study to demonstrate and assess the effectiveness of customer behavioral change from a novel communicating light switch technology that displays visual signals to residential consumers about the price of electricity.

While SCE customers have recently been transitioned to Time-Of-Use (TOU) rates, there is a gap in understanding the timing of prices during the day. With the field deployment of a smart light switch and color changing display representing time-based prices, this project sought to understand the impacts of the device on price-responsive consumer behavior, such as load shifting and curtailment.

This evaluation addressed key research questions relating to TOU response across customer groups and the incremental impact of customer load shifting beyond what behavior change customers normally provide on a time-variant pricing program or rate. Study surveys provided insight into inherent levels of customer interest regarding their energy consumption and characterization of motivating factors to energy use. Ensuring that several types of units are all proportionally represented in treatment and control, the experimental design allocated for a similar number of top floors, bottom floor, one-bedroom, and two-bedroom units to be included in both treatment and control groups.

Resident Energy Survey provided to 550 Individual Apartments

An initial project case study was locally sited in a student housing apartment community of Irvine, California. 216 residential units had the signaling device installed, at random, to serve as the test group, with the remaining 344 units in the community serving as a comparative control group.

The Flick Power light switch devices were pre-installed by an electrician. The customers' TOU rates were programmed into the switch and it displayed colored light signals to show the price of electricity during certain hours of the day: green (lowest price), orange (moderate), and red (most expensive). The research test hypothesis

was whether the device facilitates consumers to think more about energy use, whether they better understand when the peak hours are, and whether they take more actions to reduce and shift their electricity consumption.

First generation Flick Signaling Device and Accompanying Legend

To capture the incremental effects of the device on a customer's response to the TOU rate, it was optimal to have pre-treatment data from the prior year (same customer and same premise) to allow for a difference-in-differences calculation. Therefore, an initial survey was delivered to 550 housing units (216 had devices installed) to establish the usage and characterize existing user attitudes of the Vista del Campo Norte community members.

Pre- and post-survey instruments are self-administered, and web based. Door hanger flyers prompted participants to take the survey via QR code on their smartphone, tablet, or PC. The Pre-Pilot questionnaire assessed attitudes and behaviors such as the following:

- Level of interest in lowering their energy bill
- Self-assessment about how much they think about electricity usage
- Awareness of being transitioned to TOU rate
- Knowledge of current rate
- Understanding of how TOU works
- Understanding of peak hours
- Actions taken to shift/reduce

To address the research question whether customers *with* the device demonstrate any conservation or ongoing energy efficiency from lower average usage versus customers *without* a device, treatment and control groups were invited to a similar post-survey to measure effects on their awareness and behavior.

This study scope of work includes the following technical tasks:

1) Data collection, cleaning, and validation
    a. Ensure proper and complete data was received.
    b. Validate treatment assignment.
        i. Validate that pre-treatment load data is similar between treatment and

ii. control group (for TOU) and validate that the load is similar between the treatment and control group on non-event days (for ELRP).

c. Develop analysis dataset combining treatment assignment data, load data, and event data for ELRP and synthetic event days.

2) Load Analysis
   a. TOU: Conduct difference-in-differences calculation via regression model (if pre-treatment data is available) or straight differences via regression model (when not available). Regression models are used to obtain standard errors to determine if the impacts are statistically different from zero.

3) Reporting/Deliverables
   a. Develop an emerging technologies report with specified contents including description of pilot, summary statistics for pilot population, brief high-level methodology, and findings.

The project was jointly funded with ETP under the EM&T Market Assessments and Technology Assessment investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

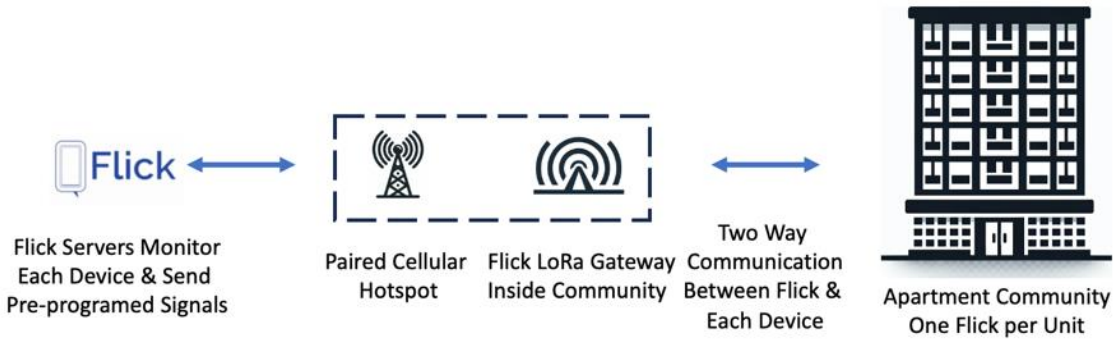
Collaboration

To implement the research study, SCE executed a service contract with an evaluation contractor with Flick Power as the technology. The Flick Power research team was also in collaboration with See Change Institute (SCI) and together have developed the lines of inquiry, study design, and messaging campaign. SCI supported the design of outreach and evaluation materials for this pilot and the project team engaged APEX Analytics for work on the load impact study design & assessment report. As part of the project team, they facilitated load change measurements and calculate impacts via regression models, with the SCE project management engineer presiding as active reviewer of work in progress.

Results/Status

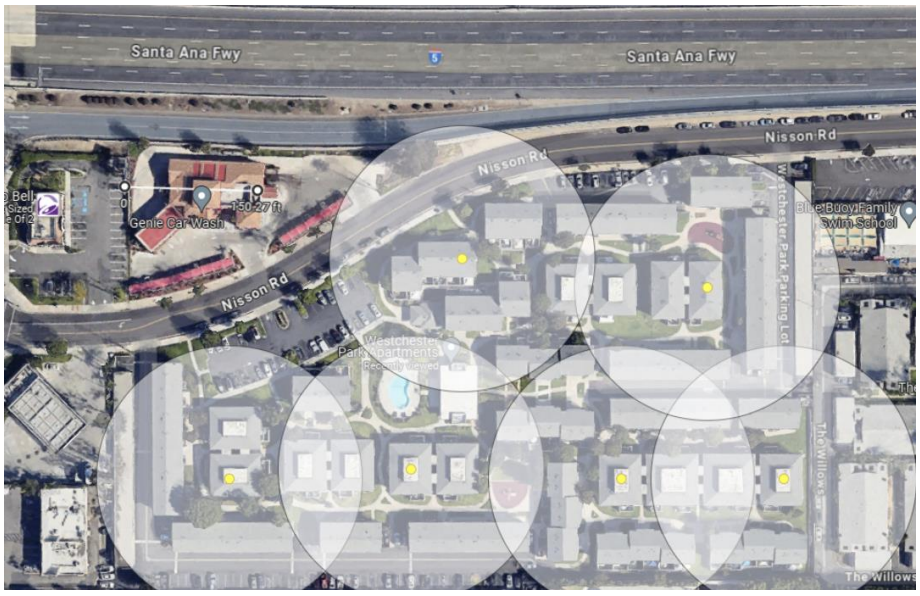
For the field study, twenty-five devices were unable to access the internet due to an Internet Service Provider (ISP) change, and the hardwired light switch devices had to be reset remotely by the vendor, causing connection disruptions and lack of comprehensive data analysis. The Flick project team devised improvements to the operational capability with a closed-loop system where the Flick team managed all

communications with devices, gateways, and its servers. This closed-loop network ensured that the study did not need to rely on end-user or property level Wi-Fi, which was virtually non-existent in multi-family and affordable housing communities.



Flick's Closed-Loop Communication System

Flick developed an approach to use LoRa WAN, a low-cost, simple, low bandwidth and far-reaching radio signal that enables a single hub or gateway placed on a property to reach units over a half mile away. A simple cellular hotspot was connected to Flick's LoRa gateway, which then communicates with Flick's backend servers. This improves communications reliability in the field tests. During the Q3 - Q4 2024 period, the project team completed installation of all the LoRa WAN devices, resident education and awareness training, and test & control surveys.



Gateways Installed to Enhance Communication Coverage

Data collection was finished around late November/early December. From the start of the fourth quarter, the project team conducted data analysis and initiated a final report that includes both the survey results and the load impact analysis.

Next Steps

The field study has been completed including the test & control surveying done in Q3 2024. A draft report has been completed including data findings of the project from Q4 2024 and is under review for publication. The full report will be available in spring 2025 at www.dret-ca.com/wp-content/uploads/2025/4/DR23.02-Flick-Power-Study.pdf.

3. Budget

The following table represents the total expenditures for SCE's 2023 - 2027 EM&T authorized budget as of December 31, 2024. These values are based on the authorized funding and expenditures as reported in SCE's Monthly Report on Interruptible Load Programs and Demand Response Programs, Table I-2, SCE Demand Response Programs and Activities Expenditures and Funding submitted on February 3, 2025.

The values in the table below do not reflect forward budget commitments for internal labor, support contractors, or project costs, including those described in this report. The future budget commitments may have been scoped and contracted, but not yet executed or monies have not yet been spent.

Southern California Edison's Emerging Markets and Technology Program 2023 – 2027	
Authorized Budget	$25,743,335
Budget Spent to date	$8,003,346

NOTE: The "Authorized Budget" amount in the table above also includes the 2022 funding authorized for the DR21.03 Dynamic Rate Pilot approved in D.21-12-015.