Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q3 – Q4 2023

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
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#	C Sharp language
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
CSI	California Solar Initiative
CZ	Climate Zone
D.	Decision (CPUC)
DAC	Disadvantaged Community
DER	Distributed Energy Resource
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
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
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
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 2023 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.

As described in SCE's 2018-2022 DR program application (A.17-01-012, et al), and approved in D.17-12-003, the SCE DR EM&T program facilitates the deployment of innovative new DR technologies, software, and system applications that may enable cost-effective customer participation and performance in SCE's DR rates, programs, and wholesale market resources. The program funds research demonstrations, studies, the assessment of advanced DR communications protocols, and conducts field trials and laboratory tests. These activities help enable the innovative high-tech and consumer markets to adopt DR methods and standards that advocate for continuous improvement in DR technological innovation.

The SCE Customer Programs and Services (CP&S) organization oversees the EM&T program's activities, which are each funded via a portfolio investment approach designed to provide maximum value for SCE's customers. The portfolio focuses on advancing DR-enabling technologies for SCE's programs, tariffs, and markets, consistent with the program's five-year approved authorization from D.17-12-003 and continued through 2023 from D.22-12-009.

The EM&T program's core investment strategies align with the guidance from D.17-12-003, and the learnings and results from each activity, study, and assessment type are shared via multiple technology transfer channels with DR stakeholders, research organizations, and policy makers. These strategies facilitate DR-enabling technology education, in-situ field testing, capture of customer perspectives, understanding of market barriers, promotion of technology transfer, and customer and program adoption.

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

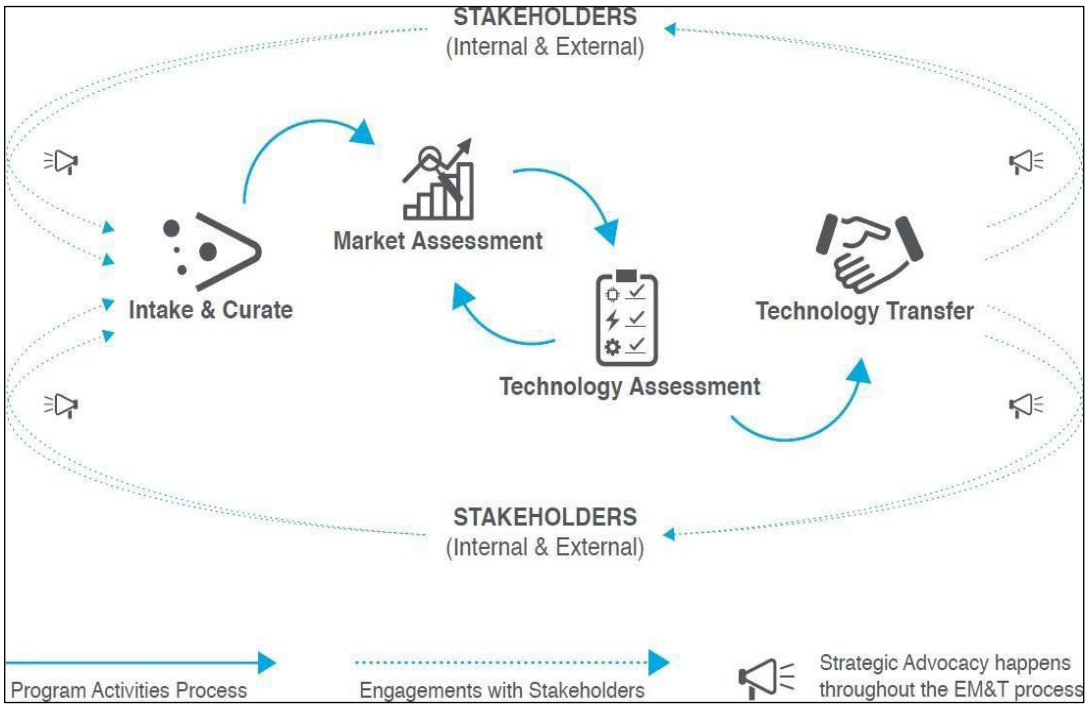
- Intake and Curation: Identifies studies, projects, or collaborations for inclusion in EM&T's portfolio and selects which ones to fund based on a well-informed understanding of the broader industry context.

- 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 lab 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 2023 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
Projects Initiated		
DR21.04	Achieving Integrated and Equitable Decarbonized Loads with the CalFlexHub	Market Assessments Technology Assessments
DR23.02	Flick Power Study	Market Assessments Technology Assessments
In-Progress Projects		
DR19.08	Grid Responsive Heat Pump Water Heater Study	Technology Assessments Technology Transfer
DR19.11	LOC-GFO-19-301-4 Optimizing Heat Pump Load Flexibility	Market Assessment Technology Assessment
DR21.03	Dynamic Rate Pilot (CalFUSE)	Technology Assessments Technology Transfer
DR22.01	LBNL Hardware in the Loop Flexible Modeling DOE FOA-0002090	Market Assessments Technology Assessments
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

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 the outcomes of their research of innovative technologies and software that could enable increased customer and stakeholder DR benefits. Many local and federally funded research studies in California are also reviewed for their opportunities for partnership funding and technology transfer into the EM&T portfolio. The EM&T program has successfully leveraged other research projects and 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.

In accordance with the CPUC direction for the reporting of the DR EM&T program, this report covers SCE DR EM&T project activities during the period between July 1, 2023, and December 31, 2023, for Q3 and Q4 of program year 2023.

1. Projects Initiated Q3 – Q4 2023

DR21.04 Achieving Integrated and Equitable Decarbonized Loads with the CalFlexHub

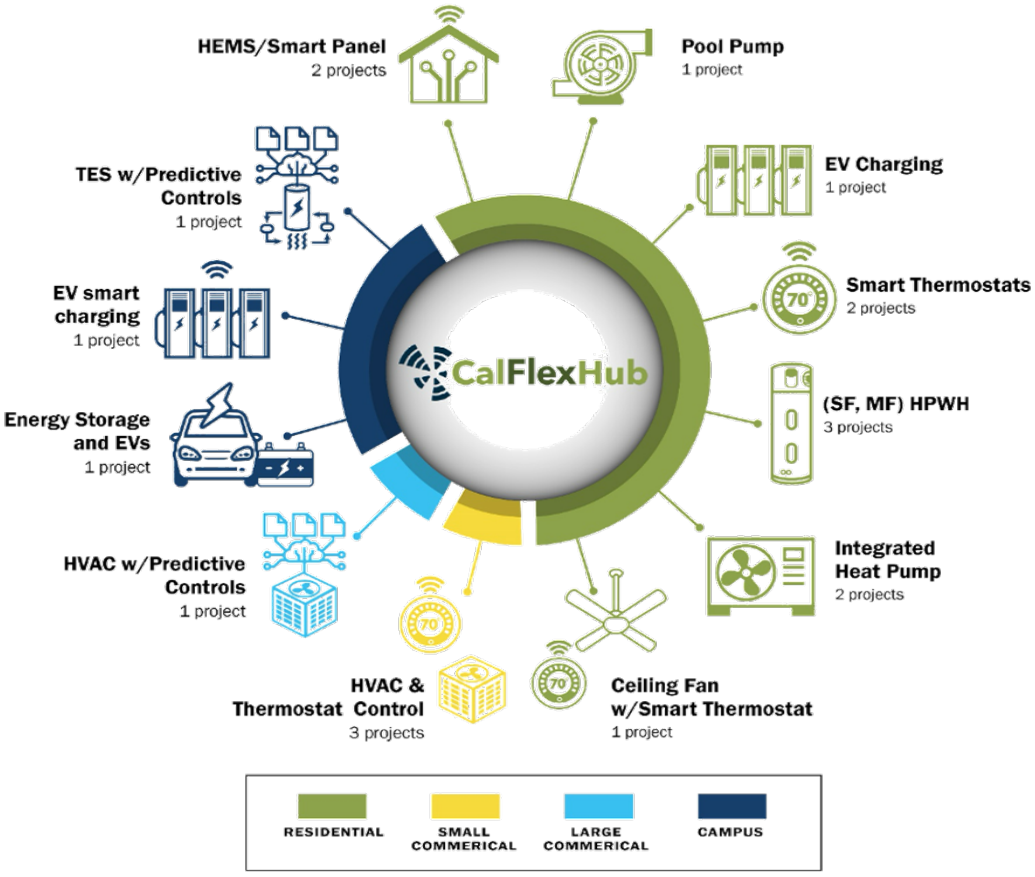
Overview

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 LF RDD&D 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 three to five 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.

The 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 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

With the SCE/LBNL agreement executed in Q3 2023, several CalFlexHub check-in meetings were conducted in Q3 and Q4 of 2023. SCE was provided with materials supporting the first two 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, including:
    - Demonstration of AI load flexibility software integrated with building controls.
        - Demonstrate AI software's ability to help small to medium commercial facilities shift load in response to hourly electricity prices.
        - Expand beyond the demonstration scope currently in CalFlexHub by including EV charging and/or stationary battery in AI-load-flexibility-software-managed loads.
    - HPWH Load Shifting
        - Connect HPWHs to advance cloud-based load shifting controls.
        - Demonstrate cost-savings of LBNL's price- and load-responsive HPWH load shifting controls.
    - Heat Pump Water Heaters and Training Center Support/Demo
        - Connect HPWHs in SCE's Energy Education Center testing facility to advanced load shifting controls.
        - Prepare demonstration and educational materials for SCE to use in training seminars.
    - Multifunctional Customer Gateway including Legacy Load Optimization
        - Demonstrate a working prototype multifunctional gateway that takes in prices with OpenADR 3.0 over a cellular connection (5G) and develop functional control of connected devices to provide load flexibility. This will be based on a current vendor gateway that currently supports Wi-Fi, Bluetooth, Zigbee, and Z-Wave.
    - Large Thermal Energy Storage
        - Determine the potential opportunities and obstacles associated with using large thermal energy storage (TES) system in SCE territory for responding to prices and other demand flexibility events.

        - Develop, deploy, and test advanced control algorithm modeling to better understand TES effectiveness in delivering demand flexibility.
    - Price-responsive controls review
        - Review existing HVAC control products and third-party software platforms available in the market that can respond to price signals and analyze their compatibility with SCE infrastructure.
        - Establish new requirements for "price-responsive" communication and control interfaces, which can serve as eligibility criteria for products participating in SCE programs.
    - EV Charging Collaboration
        - Examine opportunities for EV charging as a critical flexible load resource
        - Leverage LBNL's work on EV smart charging vision for DOE to inform SCE on its strategies for EVSE load management.

Next Steps

LBNL and SCE will continue their coordination and planning of the refined sub-project scopes listed above and finalize the desired scope of work and research outcomes through Q2 2024. Deliverables including project check-in/completion meetings, Technical Advisory Committee updates, and preliminary data reporting, are ongoing. Some selected projects specific to the SCE collaboration effort are expected to begin in Q1 - Q2 2024. The overall CalFlexHub Project at LBNL is scheduled to continue through 2025.

DR23.02 Flick Power Study

Overview

SCE's Emerging Technologies Program (ETP) and Emerging Markets and Technology (EM&T) Program 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 seeks to understand the impacts of the device on price-responsive consumer behavior, such as load shifting and curtailment.

This evaluation will address 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 will provide 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 allocates for a similar number of top floor, 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

The project case study is 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 are pre-installed by an electrician. The customers' TOU rates are programmed into the switch and its indicator displays

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 is 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 is 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 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 prompt 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 are 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

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

   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 is 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 Flick Power as the technology provider and primary partner providing technology, installation, & communication support with the pilot participants, electricians, and building managers. The Flick Power research team is 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 facilitate load change measurements and calculate impacts via regression models, with the SCE project management engineer presiding as an active reviewer of the work in progress.

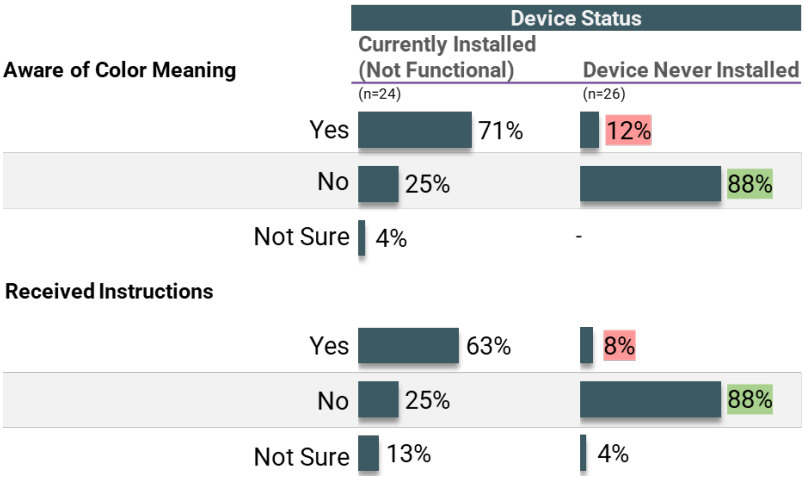
Results/Status

Educational materials were provided via door hangers to test site apartments in October 2023, with 216 devices installed. These apartments received survey

invitations in December 2023, anticipating a 15% response rate from control apartments and 20% from test apartments, to yield sample sizes of 50 for control and 43 for the test.

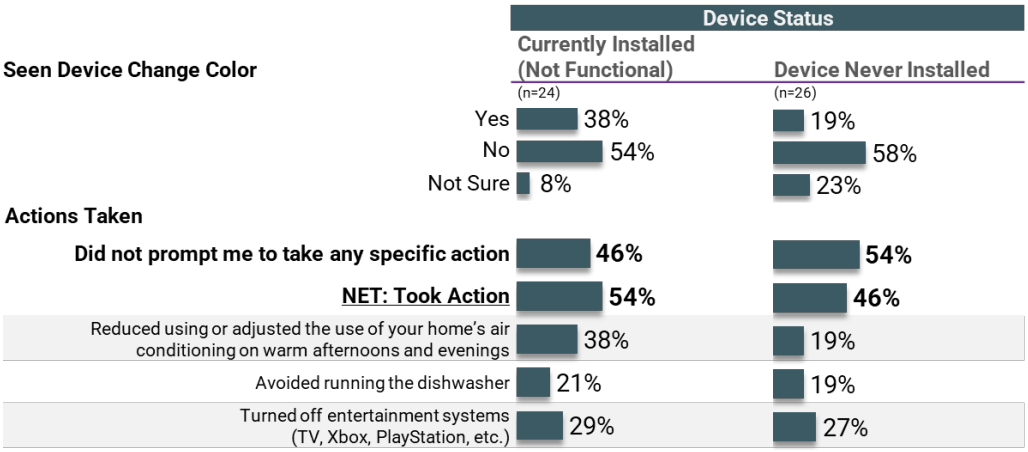
Survey Results

Data collection was conducted ongoingly during Q4 of 2023. Preliminary findings across the sites reflect the following metrics:



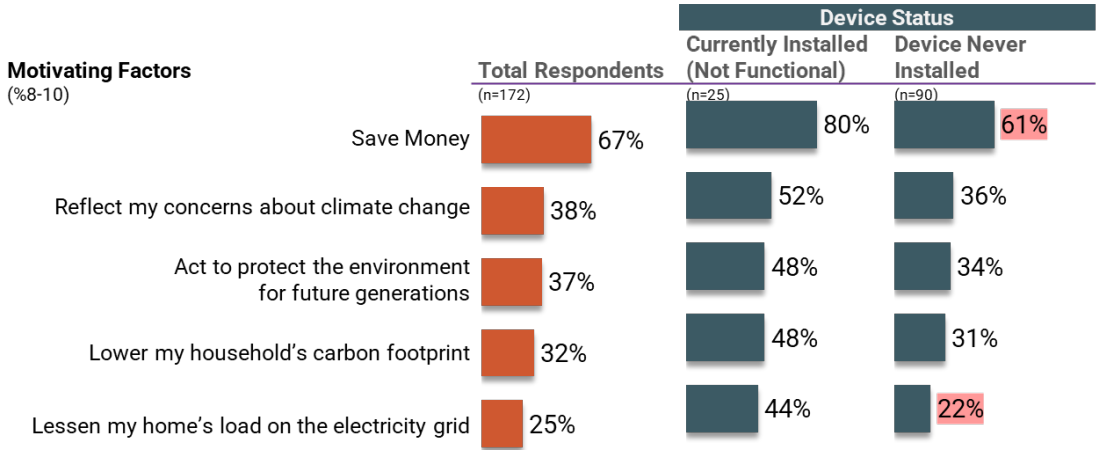
Resident Energy Survey self-reported results

Most students that were aware of the device were also aware of the distinct color meanings (71%). This was highly correlated with those who reported that they received instructions.



Resident Energy Survey self-reported results

While those reporting awareness of the color change was moderate (38%), of those that saw the colors change on the device, over half (54%) took action to reduce/shift their energy usage.



Resident Energy Survey self-reported results

Resident surveys and attitudinal characterization are complete. Based on the surveyed:

1. Most students (67%) are more concerned about saving money as a motivator for energy savings than other non-financial incentives
2. This awareness was highest when the device was installed (reflecting a treatment effect from the intervention)
3. Concern about the grid was the lowest motivating factor

Hardware Performance

The device feedback report produced several lessons learned. Twenty-five devices were unable to access the internet due to an Internet Service Provider (ISP) change. The hardwired light switch devices had to be reset remotely by the vendor, which potentially caused connection disruptions. This lesson learned prompts devising improvements to operational capability in a second-generation device as a closed loop system where Flick Power manages all communications with devices, gateways, and its servers.

Furthermore, during the period when devices could not access the internet, the devices simply flashed white. Treatment group feedback also expressed interest to "know if the device is functioning properly or not." The research team is addressing this need and incorporating an indicator for the next generation device to proactively communicate when it is not functioning.

The project's research work is providing implementation guidance for deployment of such signaling devices in multi-family and affordable housing. The research team continues to explore the applicability for increasing TOU awareness in these communities.

Next Steps

Informed by data gathered during the first phase of the pilot deployment, resident feedback, and input from property managers, the project team has developed an enhanced visual notification feature to display messaging to reinforce color signaling and drive more persistent savings compared to the first-generation light switch, which only utilizes color. The team has also proposed implementing a LoRaWAN protocol based networked system that will enable mass market and multi-family communications across multiple units without the need for a wi-fi interconnection at each residential unit. This will facilitate continuous monitoring and updates to the device and avoid internet outages.

To assess this new technology within an expanded multi-resident facility, the Flick team is developing a proposed scope of work to deploy during the next phase of the study for Q1 2024.

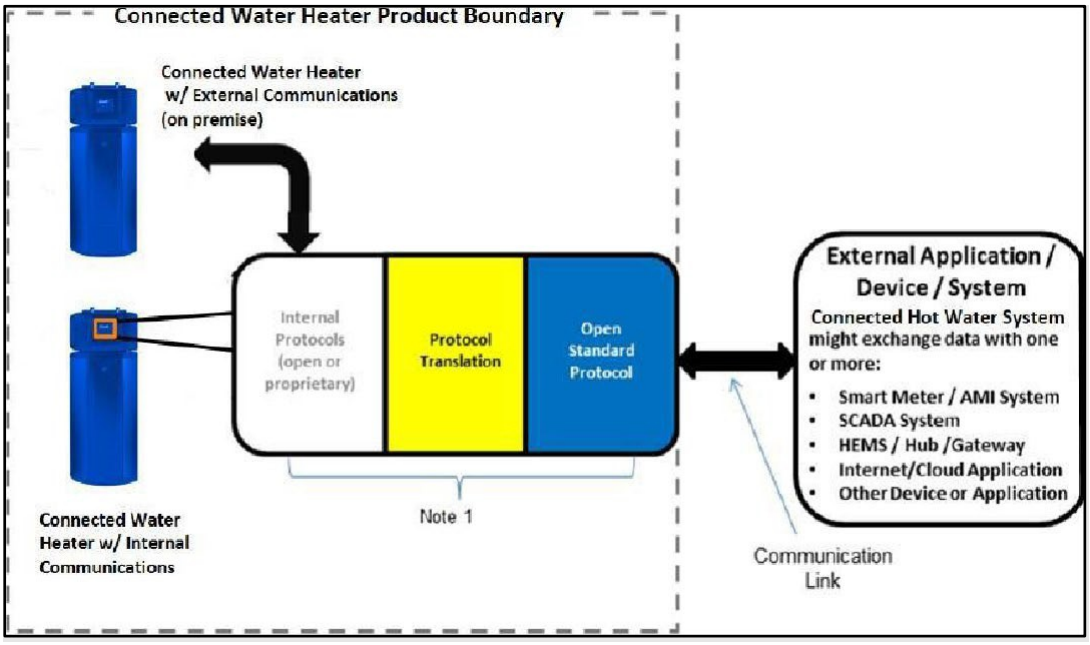
2. Projects Continued Q3 – Q4 2023

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 is 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.

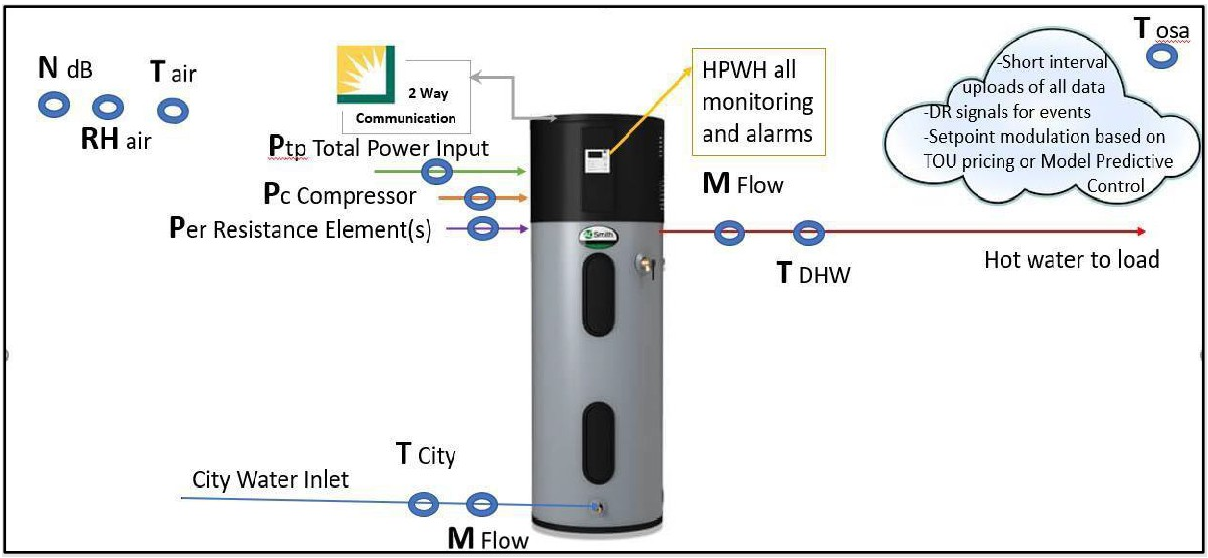
The study is in response to CPUC orders which stipulated: "Target installing local preset controls and/or digital communications technologies on 150 heat pump water heaters in each of PG&E and SCE's service territories." In response, SCE proposed the "SCE San Joaquin Valley Disadvantaged Communities Electric Pilot Implementation Plan" (SJV Pilot PIP), which was submitted to the CPUC through Advice Letter 3971-E filed on March 19, 2019.



Connected Water Heater Communications Architecture

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

The EM&T project will provide 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 12 HPWHs will have 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 is 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, SCE 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 12 homes selected have a garage for the HPWH and no recirculation system. The 12 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 will be responsible for the customer selection and the selection and installation of the grid controlled HPWH and a proposed 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 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 during the initial stages of emerging technology development for potential DR program and product offerings.

Collaboration

The research team consists of SCE's Engineering Services group under the direction of the ETP and EM&T program managers and will be assisted by SCE's technology consultants. The SCE Income Qualified Program group will oversee the SJV DAC and will work 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 will also be involved. The project is 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 for the study is still ongoing. Data collection and analysis/baseline characterization was conducted ongoingly from Q3 – Q4 of 2023. The research team experienced faulty hardware in the CTA2045 communication modules, reducing the actively communicating field sites to a singular site. Steps are being taken to determine CTA2045 module replacement options.

Baseline performance of the HPWH systems has improved during Q3-Q4 2023 due to targeted maintenance and improved programming of the HPWH systems to align with customer usage patterns. Recent preliminary findings from the active sites, with outliers removed (further analysis required), from late August through November 2023 indicate the following metrics (compared to earlier findings from Q1 – Q2 2023):

Avg Daily Energy Usage = 3.0 kWh/day

Avg Daily Peak Demand = 3.6 kW
Avg % time above 1 kW = 0.3% (minimal usage time of heating elements)
Avg Energy Factor = 2.6 (Rated UEFs were 3.75 and 3.61)
Avg Delivered Temperatures of 126.2 F
Avg Daily Hot Water Use = 64.4 gal/day
Avg Daily Hot Water Events = 60 events/day

In comparison, previous preliminary findings across all 12 sites for ~ 6 months (January through June 2023) indicated less efficient operations:

Avg Daily Energy Usage = 3.8 kWh/day
Avg Daily Peak Demand = 4.2 kW
Avg % time above 1 kW = 1.3% (minimal usage time of heating elements)
Avg Energy Factor = 2.6 (Rated UEFs were 3.75 and 3.61)
Avg Delivered Temperatures of 125.2 F
Avg Daily Hot Water Use = 69.4 gal/day
Avg Daily Hot Water Events = 64 events/day

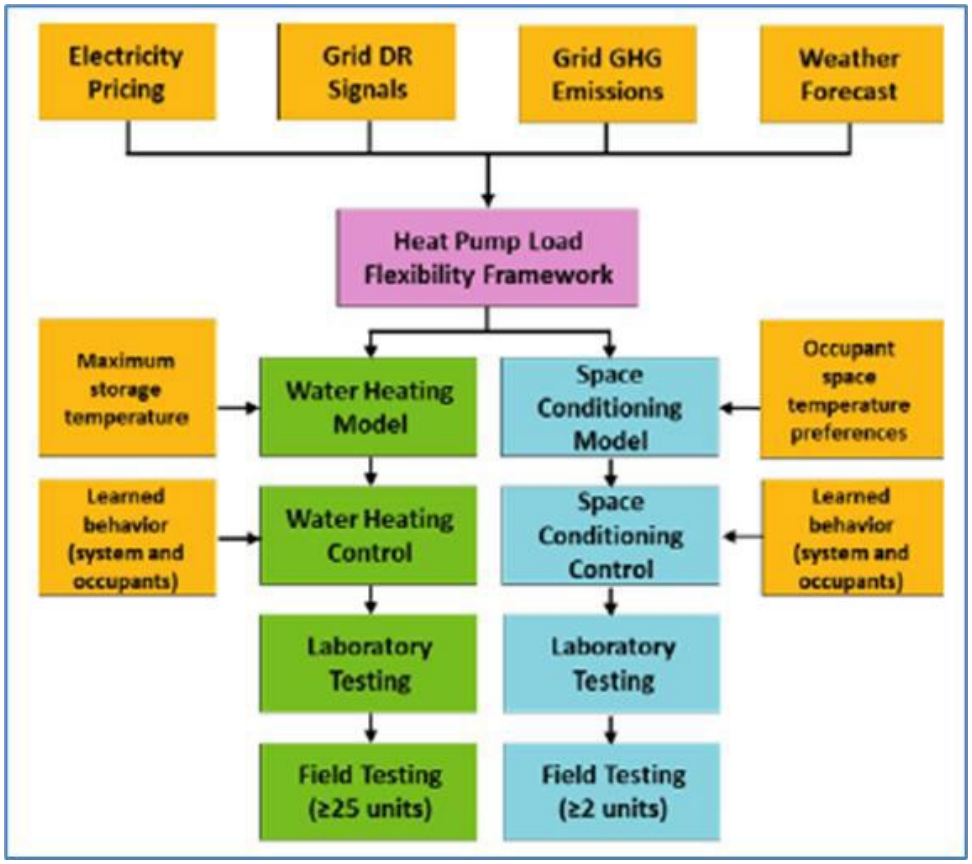
Next Steps

The project team will continue to collect and analyze data at the remote customer sites. Steps will be taken to determine if the communication modules may need to be replaced, and what feasible scope of DR testing may be accomplished by project end of the overall SJV DAC project. The project is targeted for completion with a final report completed by Q2 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).



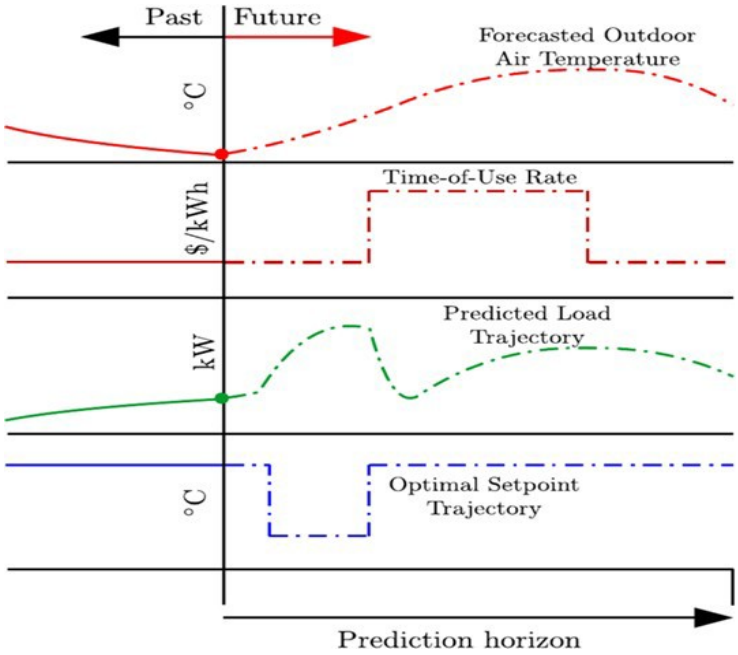
Overview of Heat Pump Load Flexibility Framework

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,

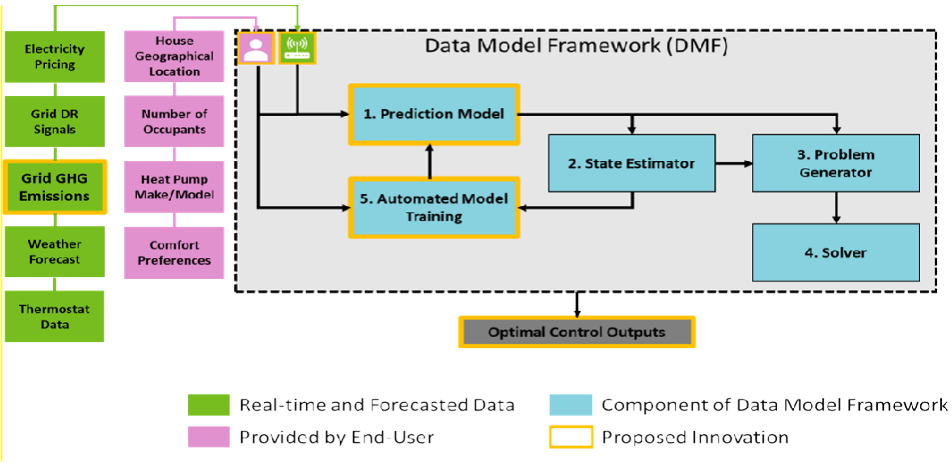
building occupant preferences must be satisfied.

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 25 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 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 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

Development of the AWHC continues but was delayed due to an unforeseen issue with real-world weather data during lab testing. This issue was resolved and the first full test with the data model framework, supervisory MPC, and lab HWPH was conducted at the end of November 2023. Due to the delay in AHWC development, the field deployment has been delayed to Q1 2024. Initial lab results have shown that the supervisory MPC is controlling the lab HPWH differently than the baseline RBC, based on the SCE TOU tariff. However, the HPWH will still run during the peak when needed to keep the tank temperature above 110°F. In Q1 2024, lab testing will expand to include the co-optimization of cost and GHG emissions in the supervisory MPC.

For ASCC development, EnergyPlus models of the field site units are being developed and validated using data collected at the two field sites. Also, the ASCC control method was formulated and is expected to be developed in Q1 2024. Once completed, ASCC testing will begin on the benchtop setup (Q2 2024).

M&V data collection continues at the twenty-six households who have been recruited for project field demonstrations. Baseline surveys for water heating and space conditioning have been completed and more will be administered once the AWHC and ASCC have been deployed.

Next Steps

The project continues to work on model development and methods for hot water use forecasts. Additionally, a state-estimator-based approach is also being developed and tested, which would allow water use to be estimated based on the in-tank temperature measurements, instead of a flow meter. The study will continue to focus on the following tasks:

- Preparing for retrofit of AWHC for Q1 2024 and monitor performance for 9 - 12 months.
- Preparing for retrofit of ASCC late Q2 or early Q3 2024 and monitor performance for 9 months.
- Start Market Barriers and Commercialization Assessment in Q2 2024.

[1] Loren dela Rosa, Caton Mande, Henry Richardson, Matthew J. Ellis. Integrating Greenhouse Gas Emissions into Model Predictive Control of Heat Pump Water Heaters. ACC 2023.

DR21.03 Dynamic Rate Pilot

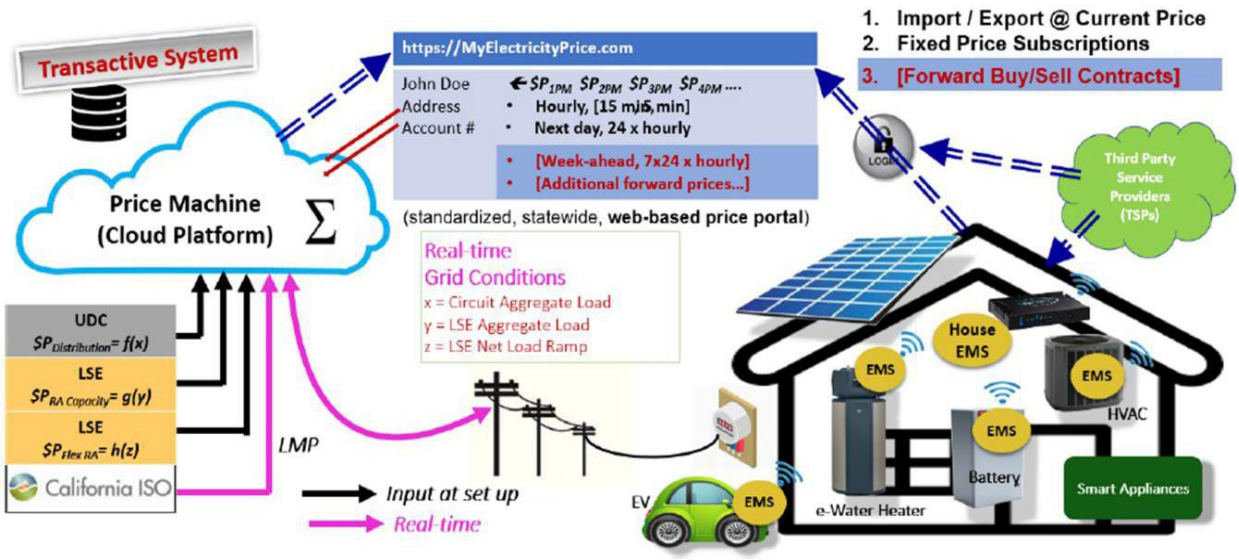
Overview

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 will combine real time pricing design and transactional subscription elements from both the RATES and UNIDE tariff concepts. The Pilot will also investigate 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.

The key operational tasks of the Pilot will be 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.

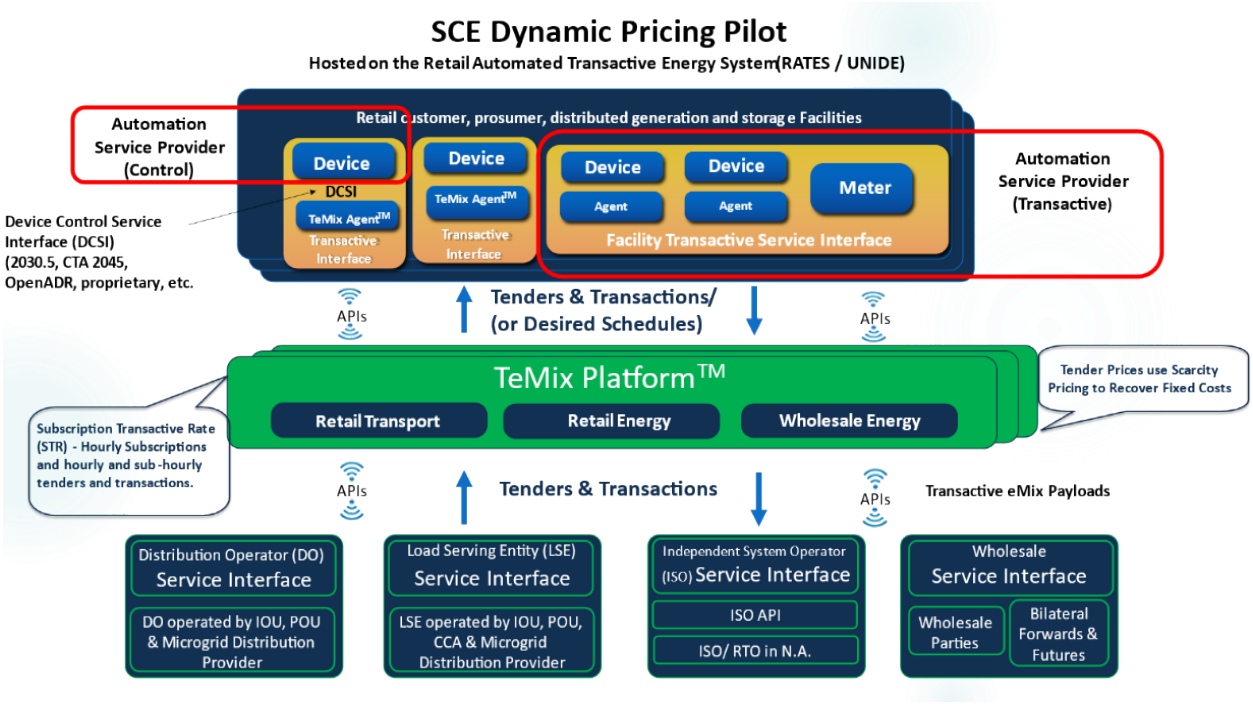
SCE was encouraged to enroll residential, commercial, and industrial customers in this exciting demonstration. SCE will work through reputable Automation Service Providers (ASPs) with existing relationships with these customer types and previously installed automation software or hardware at these customers' 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 will be provided with a tailored subscription for their monthly electricity use based on an analysis of their historical usage. During the pilot, the customer will receive 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.



CalFUSE Concept for Dynamic Rate Design

The Pilot will combine real-time pricing design and transactional subscription elements from the CalFUSE tariff architecture. For the CalFUSE hypothesis to be fully examined, the Pilot metrics will be 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. Below is the current Pilot system technology overview that includes the price machine, ASPs, and data flows for implementation.



SCE Dynamic Rate Pilot Overall Architecture

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 will transmit dynamic tariff prices securely to participating SCE retail customers during the Pilot and will also record these dynamic pricing tender transactions for settlement purposes via a "shadow bill" approach. The ASPs will integrate with the TeMix platform for 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 will be engaged to collaborate with SCE and TeMix and will be 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.

SCE is continuing to engage other innovative partners interested in collaborating with the Pilot. 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

SCE has 36 customers at various stages of the enrollment process in the Pilot, with more planned for full participation in 2024, and thus expects to fully address the Decision's evaluation requirements in the final Pilot report (scheduled by March 1, 2025).

As of December 2023, these customers enrolled have now completed their smart device(s) set-ups to receive price signals from the Pilot's dynamic rates platform. The next six months of active price signal and data results will support the delivery of customers shadow bills credit/incentives. This price signal deliveries period will be reported in the final evaluation report to provide findings more representative of the Pilot's performance (due to increased participation during summer 2024).

Next Steps

The Pilot's pricing platform will continue to provide price signals to the automation service providers and identified end-use smart devices in 2024. This is expected to enhance the Pilot findings to assess the benefits and or impacts of the dynamic rate on required infrastructure to support a new rate design, the ability to influence the interests of customers and manufacturers while measuring the costs and benefits of real-time rates, including the Pilot's evaluation deliverables:

1. An evaluation of load responsiveness.
2. The monthly bill impacts of the Pilot dynamic rate in comparison to a customer's otherwise applicable tariff (OAT).
3. An evaluation of the cost recovery to assess the impact of any under-collection of revenues associated with the Pilot.

DR22.01 LBNL Hardware in the Loop Flexible Modeling DOE FOA-0002090

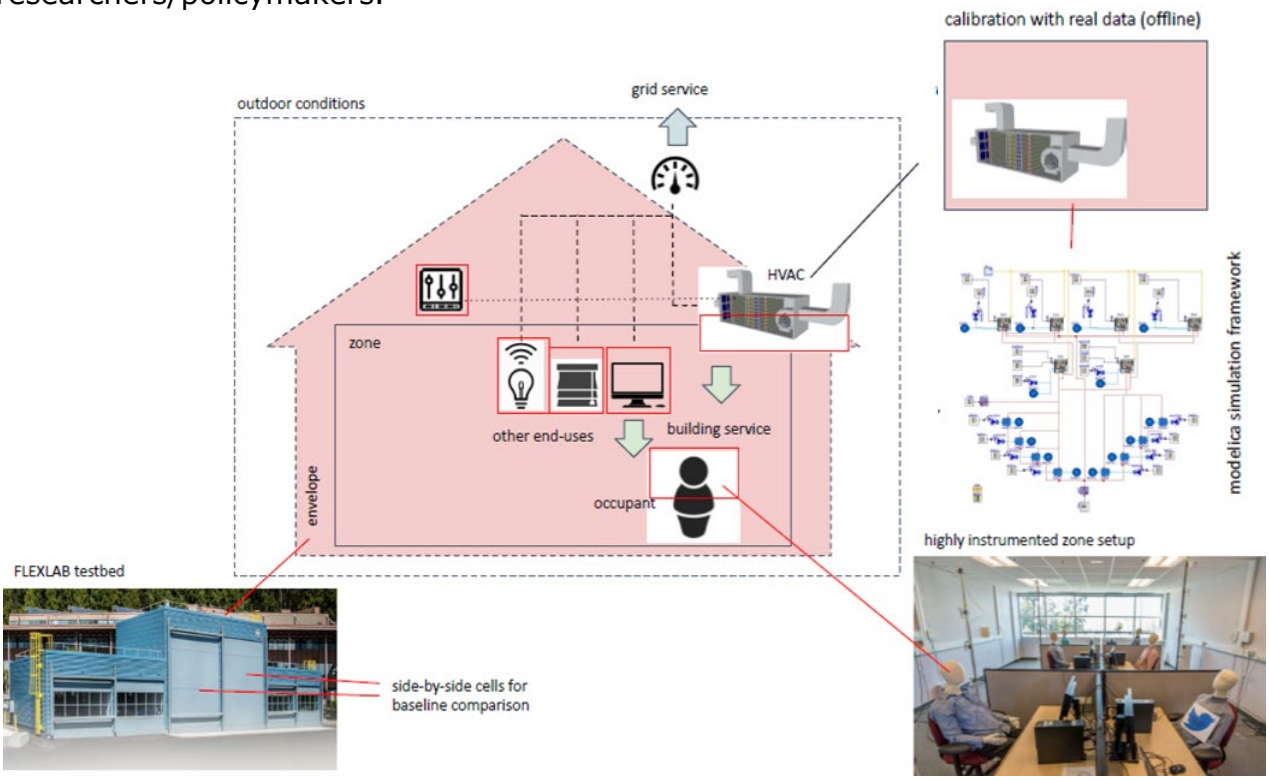
Overview

Lawrence Berkeley National Laboratory (LBNL) submitted a proposal to the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) in response to the DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019". The BTO's overall goal is to improve the energy productivity of buildings without sacrificing occupant comfort or product performance, to use energy more productively and efficiently, not simply to use less energy. According to the BTO, progress towards achieving this goal will make building energy costs more affordable to the benefit of American families and businesses, and achieving the BTO's priorities across the building technology landscape requires sustained, multifaceted innovation.

LBNL FLEXLAB Test Site

The proposal submitted by LBNL was titled "A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop (HIL) approach" and LBNL was awarded a contract agreement by the DOE for $1.6M. The overall project objectives are to measure demand flexibility for different grid services and system/building types (commercial) and generate data for researchers/policy makers. SCE provided a Letter of Commitment (LOC), intending a cost share of $300,000 to supplement the DOE's grant.

This DOE project at LBNL will generate high fidelity measurements of building system energy use and their ability and performance to provide grid services and demand flexibility while maintaining acceptable levels of service to building occupants. It will measure demand flexibility for different grid services and system/building types (commercial) and generate data for researchers/policymakers.



Overview of LBNL Hardware-in-the-Loop (HIL) Test Approach

The HIL software infrastructure architecture at LBNL has the following responsibilities:

- **Agents:** Host agents to communicate with hardware devices at LBNL's FLEXLAB, emulated hardware devices using system models and software services such as price signals and weather forecasts.
    - Hardware agents could read data points from FLEXLAB in real-time. These agents communicate with devices over multiple protocols such as Modbus, a FLEXLAB-specific protocol, and web APIs.
- **Database:** Provides a historian agent for a database to both store data being published by agents and respond to database queries from other agents.
- **Visualization:** A data dashboard for real-time visualization of equipment and model states is also hosted. It queries the data from the historian.
- **Message Bus:** Provides a message bus for the communication of data between agents and the historian. This includes:

- Ability to read from FLEXLAB points every one minute and store the data and visualize it in the dashboard.
- Ability to control points and equipment in FLEXLAB and in the software modeling language with the same interface.

Research questions include:

- How much electrical demand can be "shifted" by a light commercial building?
- What are the controllable electrical end-uses and equipment types that provide the highest shifting impact?
- How do building mass and insulation affect the amount of shiftable load?

The project objectives are:

1. Generation of high-resolution data (i.e., 1 min sampling or less) measuring the performance (building and grid service) of at least 3 systems (e.g., HVAC, lighting, plugs) while operating under all four flexibility modes (i.e., efficiency, shed, shift, modulate) in at least 5 different scenarios (e.g., a mix of weather, occupancy, building characteristics)
2. Development of test procedures to measure building flexibility
3. Generation of a component-level and system-level model of FLEXLAB to be used in future simulation research (e.g., to test advanced controls)
4. Setup of a hardware-in-the-loop infrastructure at FLEXLAB to support new lab experiments

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 supplementary to work funded by the DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019". 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. In addition to the TAC meetings, SCE will receive more timely updates for ongoing consultation and access the reports and deliverables produced for the DOE BTO contract advisors.

Results/Status

SCE and LBNL continued project coordination and information exchange and have received periodic updates on the progress of the modeling, which are part of the SCE/LBNL agreement deliverables. Remaining deliverables include the project results summary, final reporting, and a completion meeting to be presented to SCE stakeholders. Project progress was delayed, and the remaining deliverables are forecasted to be provided in Q1 - Q2 2024.

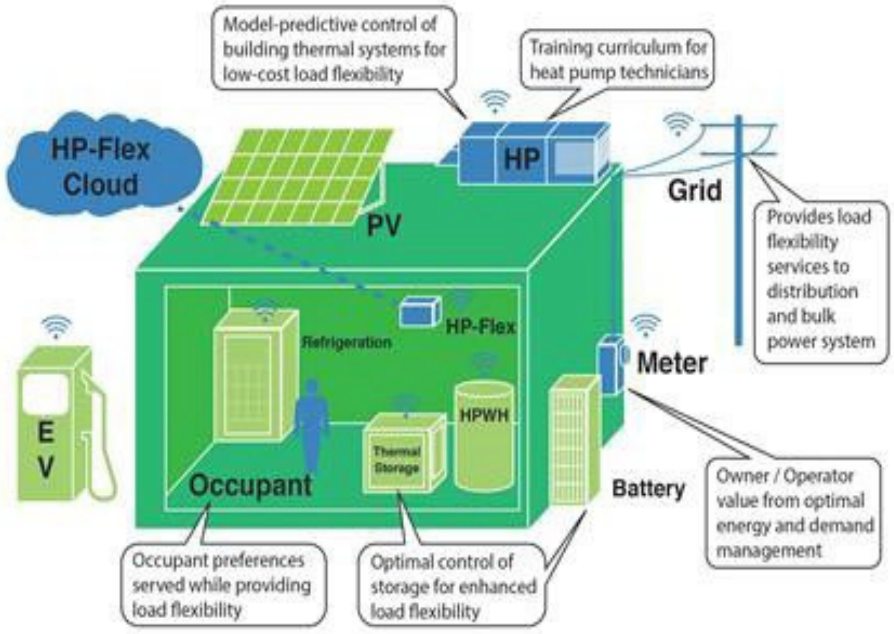
Next Steps

LBNL and SCE will continue their coordination and transfer of key findings and outcomes as the project progresses. The SCE project team will confirm receipt and acceptance of the remaining deliverables, including the project completion meeting. These deliverables are dependent on the DOE BTO contract final report, which is expected to be completed in Q1 - Q2 2024.

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 provided SCE with the first project deliverable, which gives an overview of the heat pump load flexibility Model-Predictive Controls (MPC) that were developed, and reports on the initial controls validation & testing conducted so far (simulation case study, FLEXLAB lab testing, and a NYSERDA-funded cost-share field demonstration project). The controls software was set to provide load flexibility for heat pumps while maintaining zone air temperature within an acceptable range, in response to dynamic price signals. The software has been designed to handle buildings with multiple individual heat pump (HP) units but extended to dual-fuel heat pump systems and variable refrigerant flow (VRF) HP systems. To enhance prediction performance, the controls integrate a hybrid modeling approach that models building physics and unmeasured disturbances.

Initial simulation and lab tests demonstrated a shift of up to 45% of heating loads for the morning peak period, resulting in energy cost savings of 10% to 15%. In a field test conducted for a dual-fuel heat pump system, the MPC achieved a 23.4% reduction in peak thermal load by shifting it to the early morning. The MPC also successfully reduced electricity peak demand by 14% through load shifting, while eliminating the need for a gas furnace and thus reducing greenhouse gas (GHG) emissions.

These early findings show good promise in the effectiveness of the HPFLEX-MPC in reducing heating operations during peak times, achieving cost savings, and contributing to peak demand reduction and grid decarbonization. The project encountered delays in the site recruitment efforts for the follow-up field deployment (3 or more buildings in SCE service territory).

Next Steps

Testing and software development is ongoing at LBNL. Both LBNL and SCE will continue ongoing coordination on the project activities and deliverables through online seminar updates, including any further controls testing or design & development of the software as the project continues. The research team will decide applicability of additional updates, field deployment, M&V, & information dissemination/transfer activities. A preliminary findings meeting is expected to occur during Q2 - Q3 2024.

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 is pursuing updates to its testing capabilities.

Dynamic testing or load-based testing is necessary to better characterize the performance of the actual advanced controls of these 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 could 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 was 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

Vendor selection efforts through requests for proposal were unsuccessful in Q3 - Q4 2023 and subsequently test chamber design could not be finalized. The vendor solicitation and selection approach has been restructured to explore more available options to mitigate current timeline & cost uncertainties. Vendor selection is currently projected to be finalized by Q2 2024. Project design phase is expected to occur in Q3 - Q4 2024.

Next Steps

The TTC team will finalize the design vendor selection by Q2 2024. This will enable the team to finalize the design phase by Q4 2024, and the overall construction phase for complete functional test chamber completion is expected by Q4 2025.

3. Budget

The following table represents the total expenditures for SCE's 2023 EM&T authorized budget as of December 31, 2023. 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 January 31, 2024.

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 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 (D.21-12-015 and D.22-12-009)	
Authorized Budget	$7,000,000
Budget Spent to date	$4,462,875

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.