Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q1 – Q2 2024

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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
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
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
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 Q1 – Q2 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:

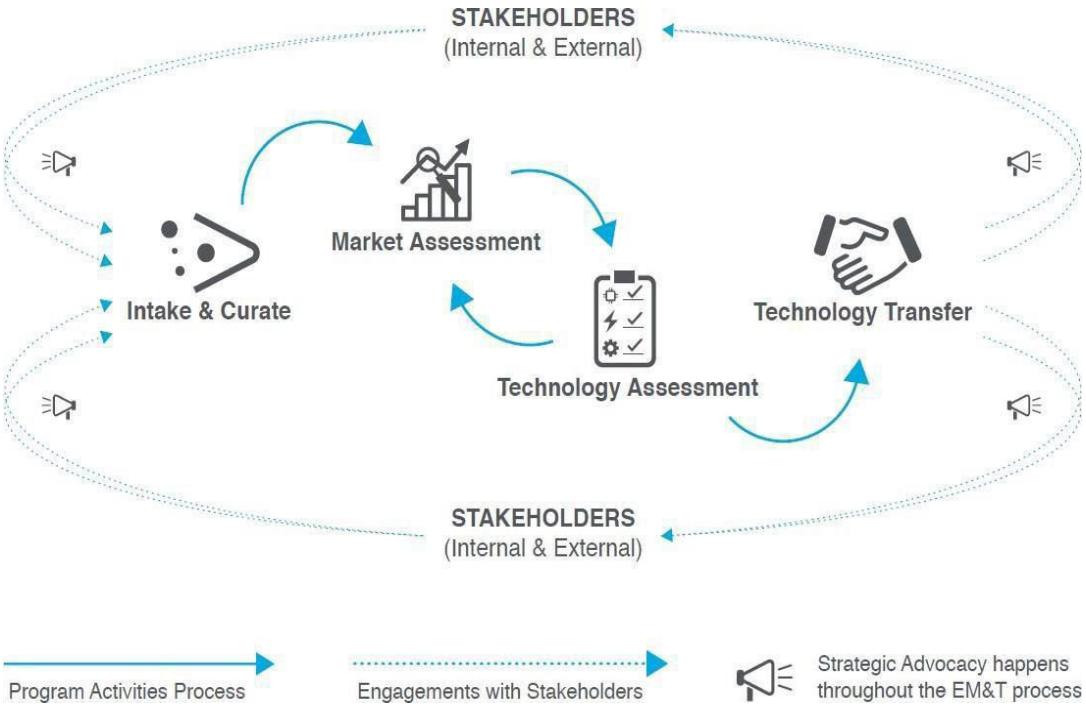
- Intake and Curation: Identifies studies, projects, or collaborations for inclusion in EM&T's portfolio and selects which ones to fund based on a well-informed understanding of the broader industry context.

- 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 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 Q1 – Q2 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
Projects Initiated		
DR24.01	Behind the Meter Optimization of Load Technologies (BOLT) Study	Market Assessments Technology Assessment
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
DR21.04	Achieving Integrated and Equitable Decarbonized Loads with the CalFlexHub	Market Assessments Technology Assessments
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
DR23.02	Flick Power Study	Market Assessments Technology Assessments
Projects Completed		
DR22.01	LBNL Hardware in the Loop Flexible Modeling DOE FOA-0002090	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 SCE DR EM&T program activities during the period between January 1, 2024, and June 30, 2024, for Q1 and Q2 of program year 2024.

1. Projects Initiated Q1 – Q2 2024

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

Overview

The Emerging Markets and Technology (EM&T) program examines emerging markets and assesses technology advancements to develop a forward-thinking approach to cost-effectively revolutionize Southern California Edison's (SCE) future demand response (DR) customer programs. For 2024, the 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 potential flexible and 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 will be 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.

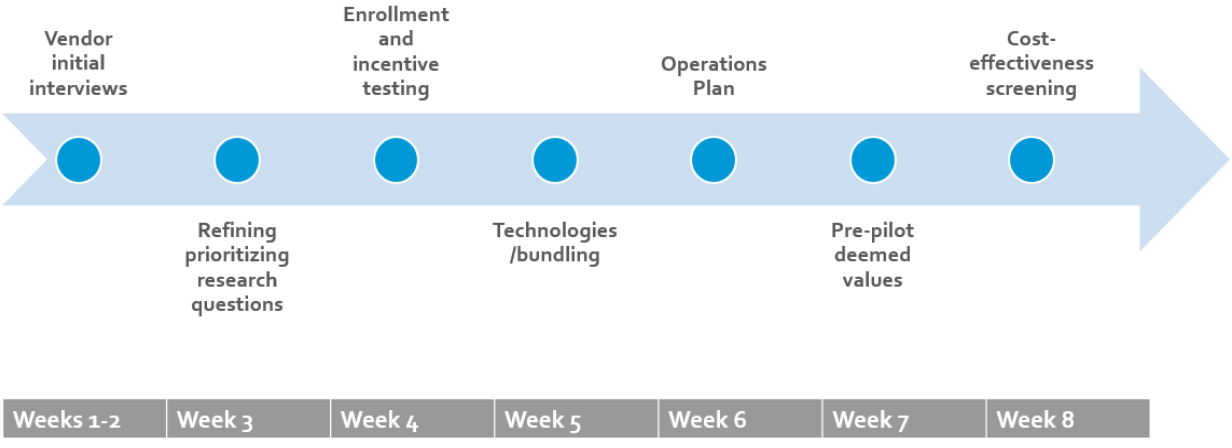
Results/Status

The study has developed the following initial research objectives:

1. Determine technology and incentive requirements to allow SCE customers to enroll various devices and end uses via a single program rather than via piece-meal, technology specific programs.
2. Make load management nimble by enabling the mid-cycle inclusion of new technologies and vendors - reevaluate technologies moving forward mid-cycle.
3. Technologies included in the BOLT study are Thermostats, EVs, Batteries, Water Heaters, Pool Pumps, and Other (acknowledging future technologies that may develop i.e., smart panels).
4. Cost-effectiveness of a future program design.
5. Optimize load dispatch to be more controllable and minimize customer impacts (loading order).
6. Update the payment for tech end-uses (e.g., value of AC load reductions).

Study Design Testing Incentives:

- Testing different up-front incentives (e.g., sign-up bonus) to understand how incentives affect the customer sign-up relationship.
- Goal - Four testing groups for comparison and control evaluations.



Schedule for Design Workshops

Marketing Intensities:

- How many phases?

- Methods: Promotional gifts, boost customer engagement. Most customers do not respond to letters/written communications.
- Will discuss who will coordinate customer recruitment: SCE, Vendor, etc

Operations Plan

- Intentionally introduce variation in weather, duration, start times, and day types
- Side-by-side tests to disentangle effects of tech bundles
- Side-by-side testing of location specific impacts
- Randomly assign population to 10 groups to allow side by side testing, without exhausting participants

The project field test design intends for dispatching many events overall to collect representative data; however, each customer will only experience a handful of events.

Next Steps

The SCE Project Team is finalizing the BOLT study's demonstration vendors' SOW, customer enrollment, and operational plans. The design team will be completing potential event scheduling applications across all potential technology types. The project team with its contractor has in development a conjoint analysis survey for Q3 2024 to measure what smart device owners value most about a given product or service, to collect precise customer type profiles to make more informed DR product and assess pricing opportunities. The project team is working to have customer technology provider signoffs by Q4 2024 to initiate customer enrollments before the end of 2024.

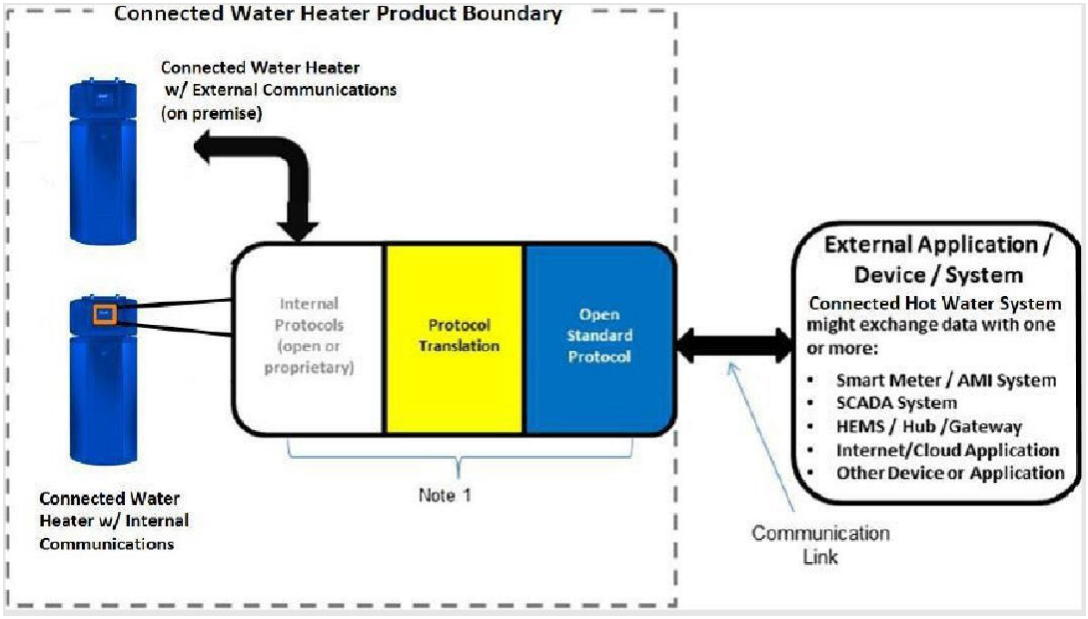
2. Projects Continued Q1 – Q2 2024

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 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.

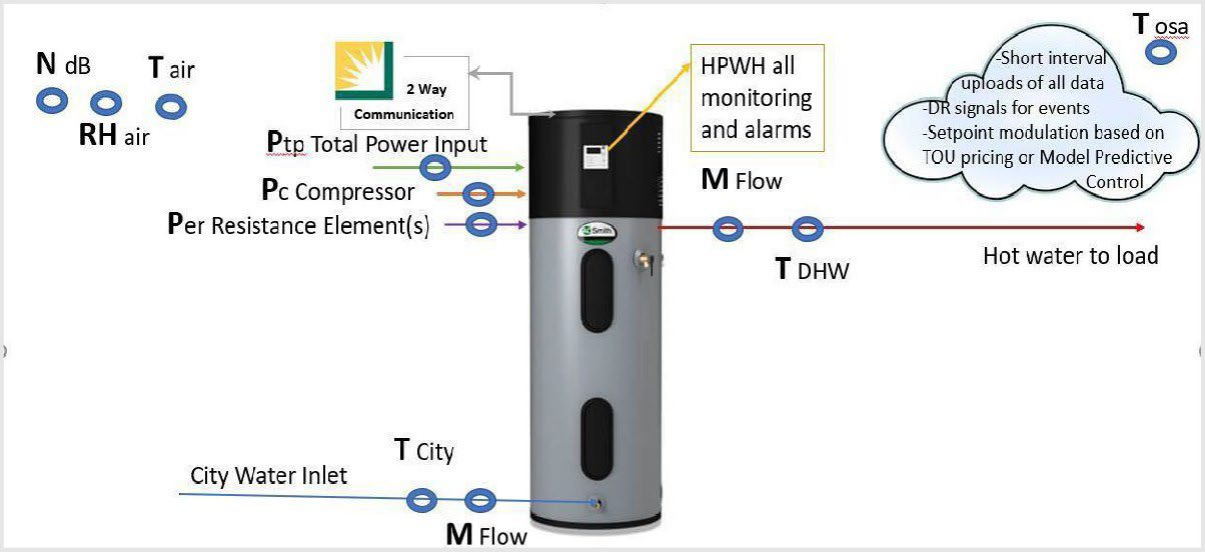
The study is in response to CPUC orders which stipulated: "Target installing local preset controls and/or digital communications technologies on 150 heat pump water heaters in each of PG&E and SCE's service territories." In response, SCE proposed the "SCE San Joaquin Valley Disadvantaged Communities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



Connected Water Heater Communications Architecture

As part of San Joaquin Valley (SJV) Disadvantaged Communities (DAC) Pilot Projects, SCE deploys electric HPWHs equipped with smart-grid communication technology that 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 portion of the project provides 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, 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 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 are 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 is 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 consists of SCE's Engineering Services group under the direction of the ETP and EM&T program managers and is assisted by SCE's technology consultants. The SCE Income Qualified Program group oversees 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 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 has been completed. Data collection and analysis /baseline characterization was conducted through Q2 of 2024. However, from the collective decision determined by CPUC Advice Letter, AL 5263-E, the DAC HPWH project has now reached closure. The research team experienced faulty hardware in the CTA2045 communication modules, resulting in a reduction in DR field testing scope. Analysis and reporting are expected to be completed in Q3 – Q4 2024.

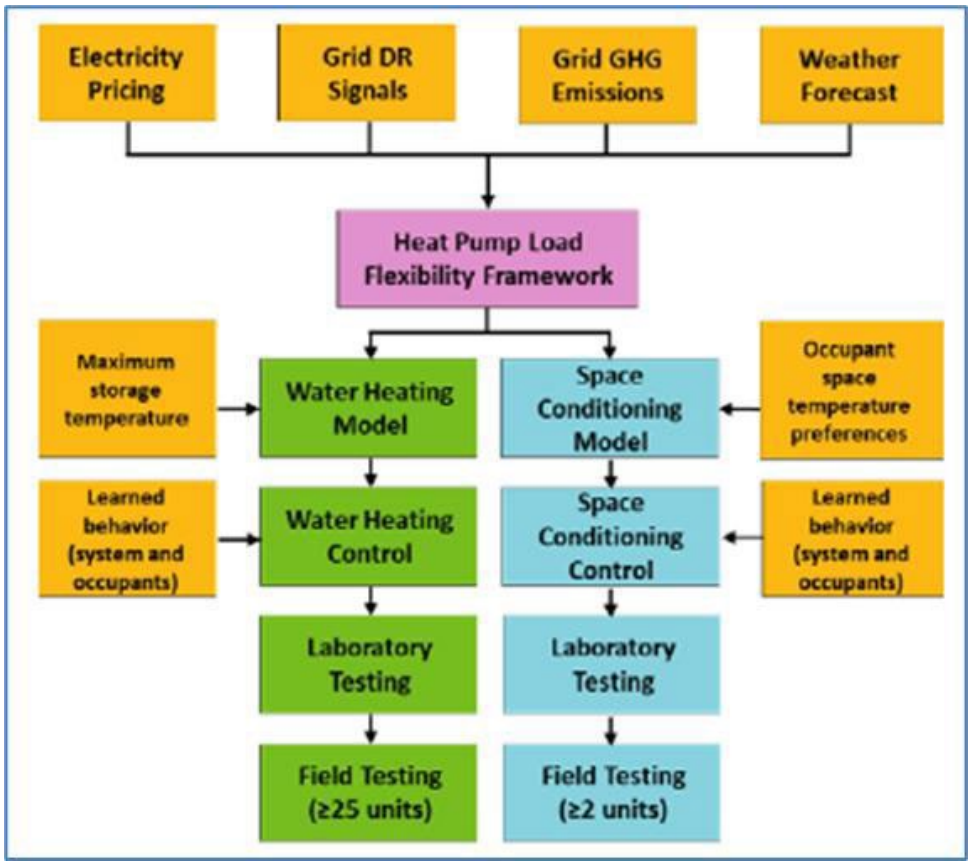
Next Steps

The project team will continue to finalize analysis and reporting as the overall DAC project winds down in Q3 2024. The baseline HPWH aspect of the project is targeted for completion with a final report completed by Q4 2024. The EM&T team is investigating the potential for a new project to assess grid responsive HPWH testing in collaboration with SCE Codes and Standards in the coming months.

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).



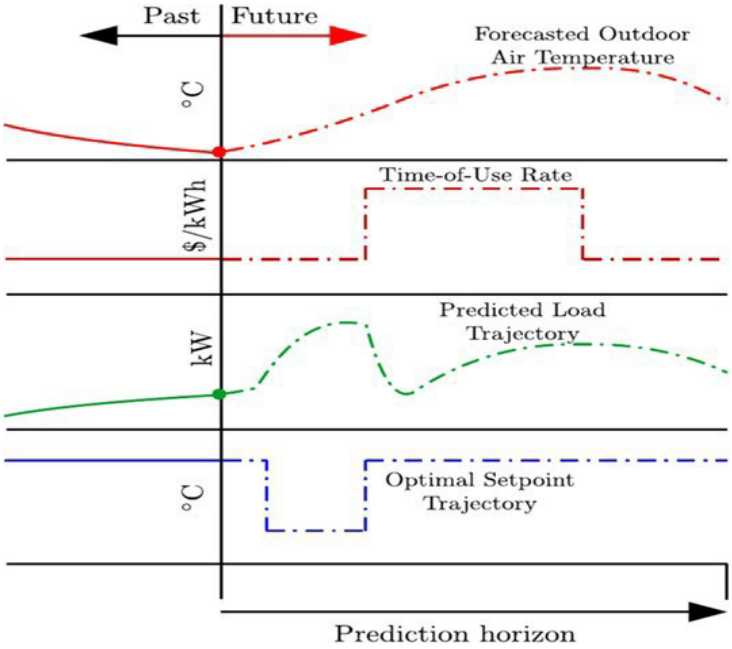
Overview of Heat Pump Load Flexibility Framework

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

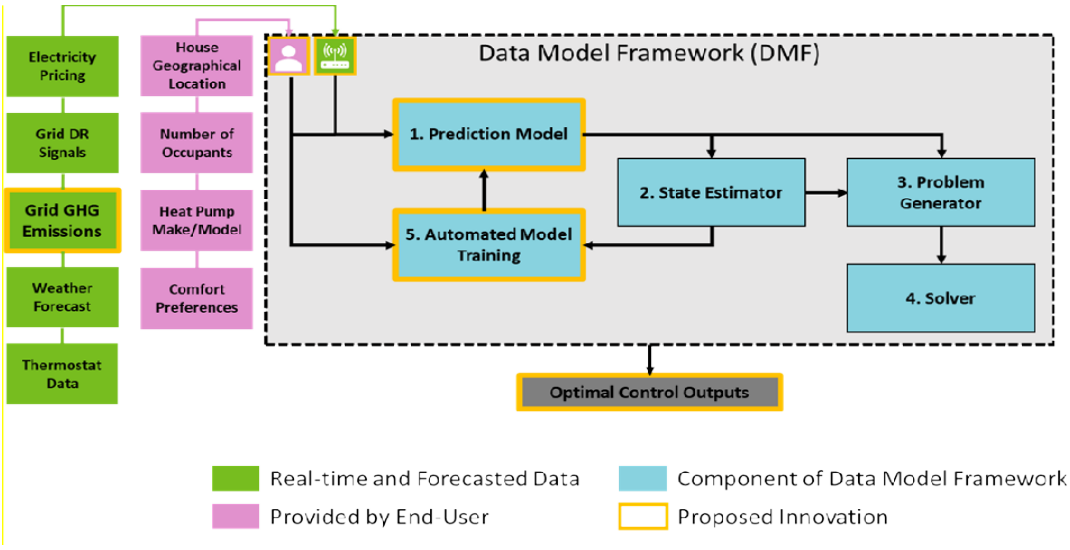
compromising their comfort. For load flexibility controls to be widely adopted, building occupant preferences must be satisfied.

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

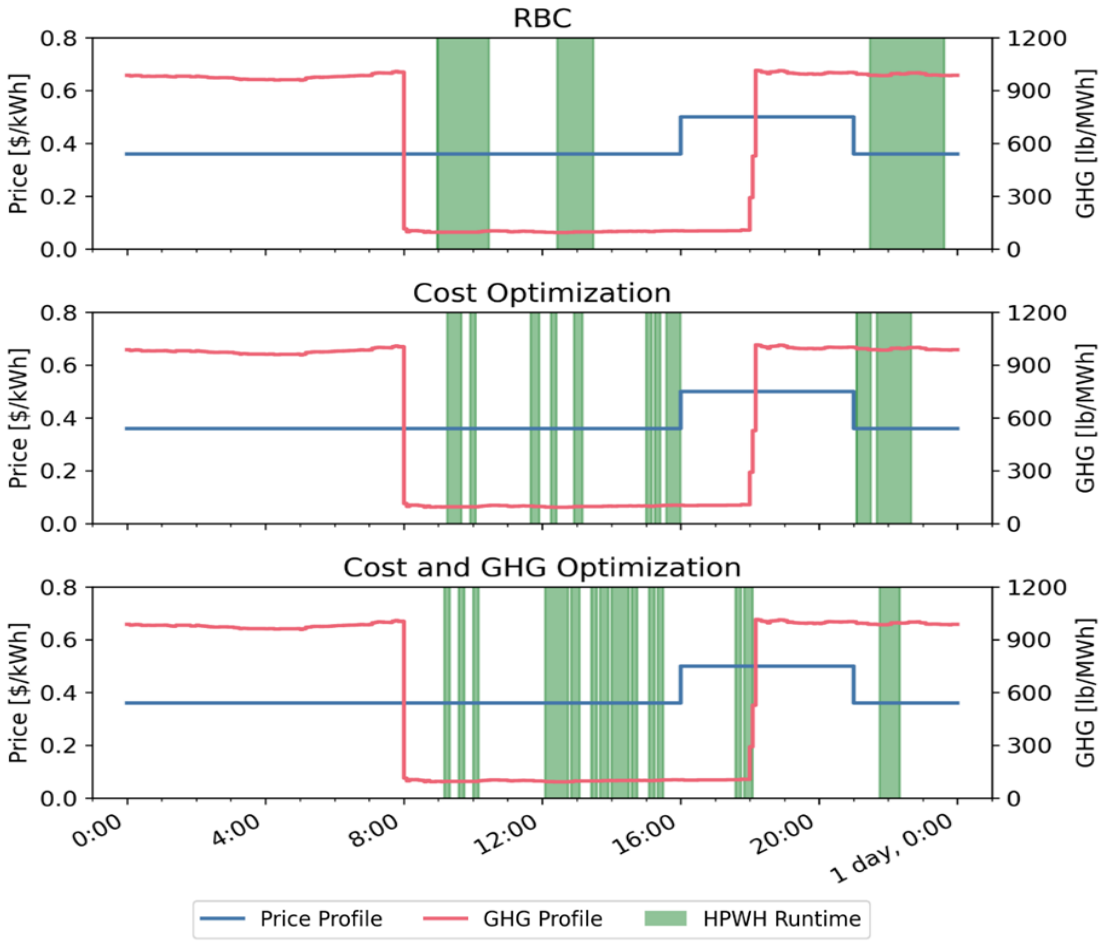
The EM&T program is co-funding the project through a Letter of Commitment for the CEC EPIC contract that is led by the UC Davis's Western Cooling Efficiency Center (WCEC) with other grant partners. While the EM&T program is co-funding the project through a contract with WCEC, SCE is also leveraging its 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

Field deployment of the AHWC began during Q1/Q2 2024. Development of the data model framework encountered a couple unexpected issues related to needs for lab testing and scalability that impacted the field deployment timeline. The issue related to lab testing has been resolved and the project team is running tests on the lab HPWH using the data model framework, supervisory MPC, and a blended const function that co-optimizes cost and GHG emissions.

The testing conducted during Q1 and Q2 2024 were investigating an upper and lower load flexibility potential of the supervisory MPC compared to the baseline rule-based control (RBC), based on an example Time-Of-Use (TOU) tariff and hot water use profiles measured at the field sites. For the supervisory MPC, two cost functions were used for each hot water profile: cost-only and cost and GHG.

Figure 1 below shows the testing results for when RBC does not need to operate during peak and the supervisory MPC cannot shift more load to off-peak periods.



Results for no RBC peak runtime

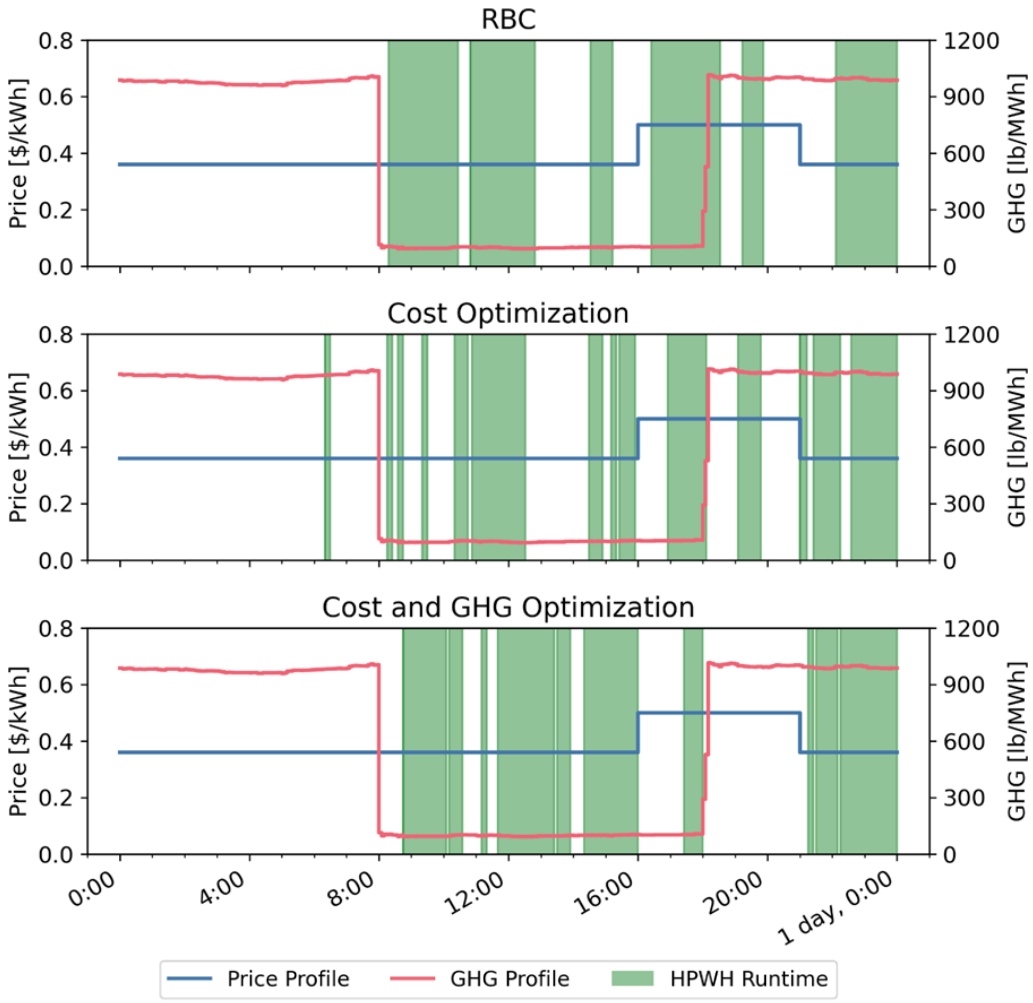
For cost-only, the supervisory MPC reduced cost by 29 percent, which also had a corresponded GHG emissions reduction of 33 percent (Table 1). For cost and GHG, the supervisory MPC added runtime during peak, but only when GHG emissions are the lowest, which reduced the post peak runtime. Based on the blended cost function, the period of high electricity price and high GHG is considered the highest cost during the 24-hour test period. In this test case, the supervisory MPC reduce cost by 14 percent and GHG emissions by 61 percent (see below).

	RBC Baseline	MPC cost only	Percent change	MPC cost and GHG	Percent change
Cost [$]	0.557	0.397	-29	0.481	-14
CO2 [lb]	0.771	0.514	-33	0.301	-61
Peak Price Runtime [min]	0	0	-	25	-
Peak GHG Runtime [min]	129	85	-34	35	-73

Tabulated results for no RBC peak runtime case

The following figure shows the results for another hot water use profile that was used to investigate the upper limit of load flexibility using the supervisory MPC. This water draw profile was measured at the field site and RBC was expected to run for the

whole 5-hour peak period, however, in the lab it only ran for 2 hours 47 minutes. This difference is most likely due to the lab test initialization process which makes each test start with a consistent tank temperature profile.



Results for 2 hours 47 minutes of RBC peak runtime

For cost only, the supervisory MPC reduced cost by 19 percent, increased GHG emissions by 4 percent, and reduced peak runtime by 35 percent (see below). Additionally, for cost and GHG, the supervisory MPC reduced cost by 15 percent, reduced GHG by 15 percent and reduced peak runtime by 79 percent.

	RBC Baseline	MPC cost only	Percent change	MPC cost and GHG	Percent change
Cost [$]	1.266	1.023	-19	1.075	-15
CO2 [lb]	1.175	1.222	+4	0.999	-15
Peak Price Runtime [min]	167	115	-31	35	-79
Peak GHG Runtime [min]	175	201	+15	155	-11

Tabulated results for 2 hours 47 minutes of RBC peak runtime

For the ASCC model, which is still in development, the EnergyPlus models of the field site units are being validated using data collected at the two field sites. Furthermore, the ASCC control method that has been formulated during Q1 of 2024. ASCC field testing is expected to start in Q3 2024.

M&V data collection is ongoing at the twenty-six households who were recruited for project field demonstrations. Baseline surveys for water heating and space conditioning have been completed and additional surveys will be administered after both the AWHC and ASCC have been deployed. The project continues to work on the adjustments to the testing protocols.

Next Steps

The project continues to fine-tune the model development and methods for hot water use forecasts and to examine how costs of operation can be optimized with peak demands and high-priced electricity periods. 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 using a flow meter.

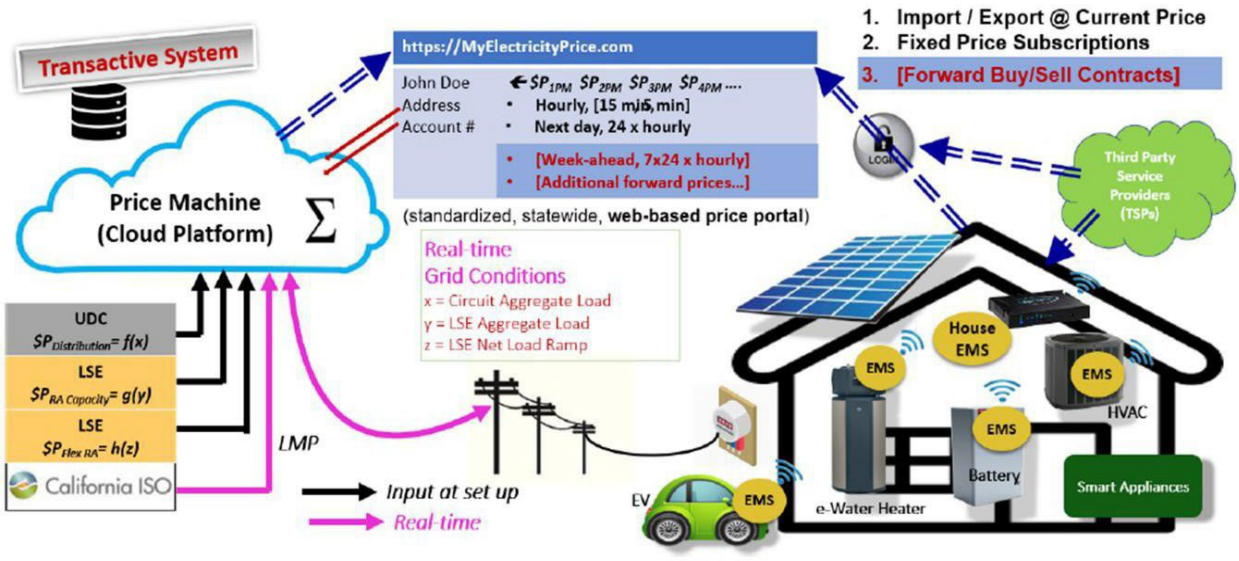
The study will continue to focus on monitoring performance of the AWHC for nine to twelve months and preparing for ASCC retrofit in Q4 2024, then monitoring its performance for six to nine months. UC Davis and SCE will continue to coordinate on updating the project timeline and reviewing and finalizing interim testing results and deliverables. The research team at UC Davis, as part of their scope of work with the CEC, will also continue progress on a Market Barriers and Commercialization Assessment through Q1 2025.

The UC Davis team will also share its lessons learned with the LBNL project team from the five new sites, testing hardware retrofit compared to software-only upgrade, testing the portability of open-source software to commercial partners, and testing longer series and other types of prices.

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.



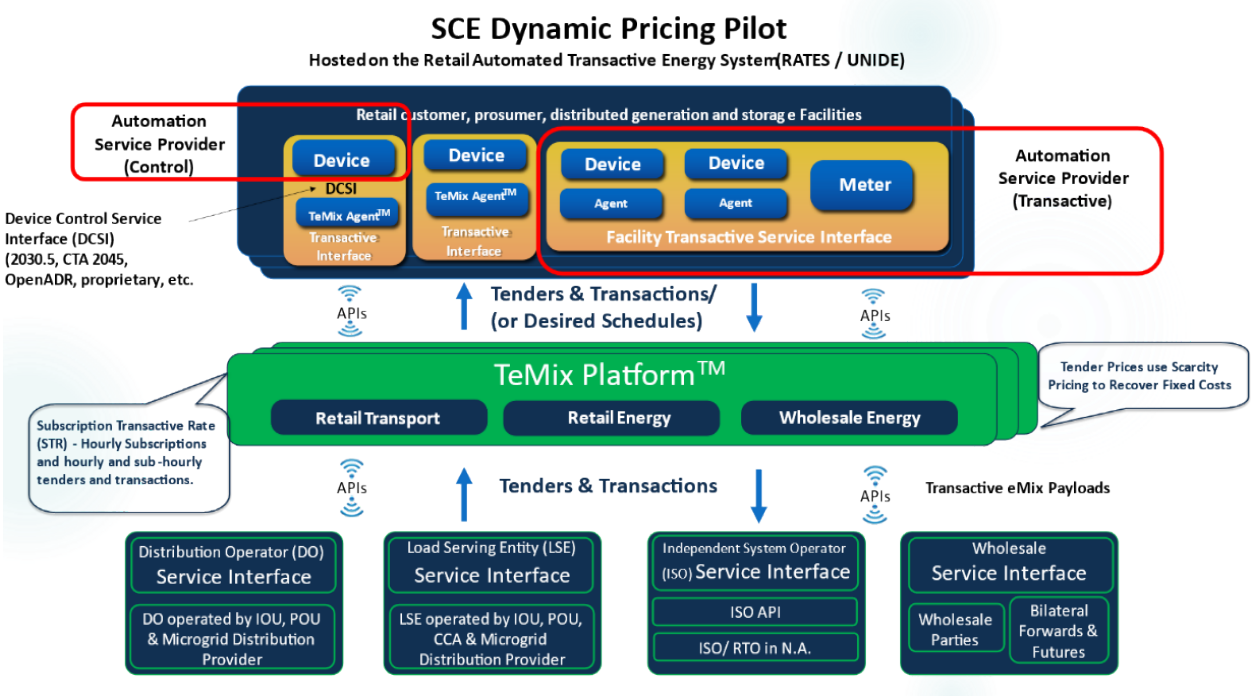
CalFUSE Concept for Dynamic Rate Design

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.

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.

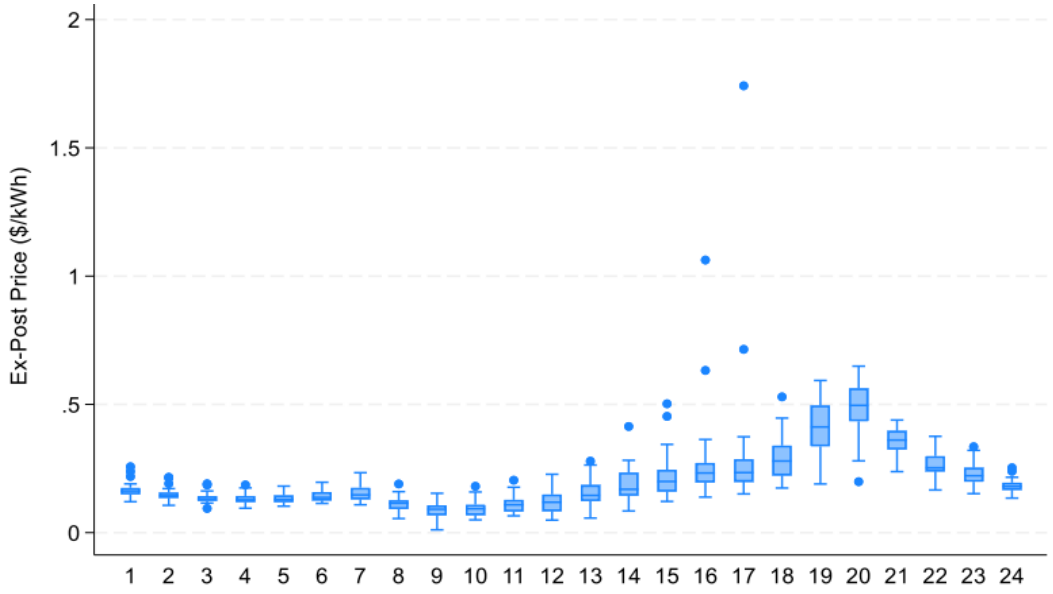
SCE is working with other stakeholders such as major electric vehicle (EV) manufacturers and/or smart charger service providers, solar/battery aggregators or service providers, and others with the capability to directly receive dynamic price tenders from TeMix and optimize (on behalf of the customer) 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

There are initial Pilot findings on load impacts and bill savings that are being assessed in the TeMix shadow billing provided to SCE billing validation team. The benefits and/or impacts of the dynamic rates compared to the customer's historical subscription is being assessed in the TeMix's detailed summaries and rate comparison reports to the customer's otherwise applicable tariff (OAT). The SCE Pilot team is conducting analysis that identifies which days to draw comparisons, and below are illustrations of graphs generated to compare ex post dynamic prices periods and weather correlation.



August Hourly Dynamic Price Summary

August Daily Average Prices, Maximum Prices, and Cooling Degree Days

The Pilot is currently communicating dynamic prices to customers and shadow bills are being generated for SCE billing team analysis. SCE currently has approximately three dozen residential and commercial Pilot participants at various stages of the Pilot's shadow bill process that will continue to see the flexible rates through the end of the 2024.

Next Steps

The Pilot's dynamic pricing platform is continuing to provide day-ahead hourly price signals to the automation service providers and identified end-use smart devices in 2024. The project team is on schedule to address the Decision's evaluation requirements in the final Pilot report (scheduled March 1, 2025).

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

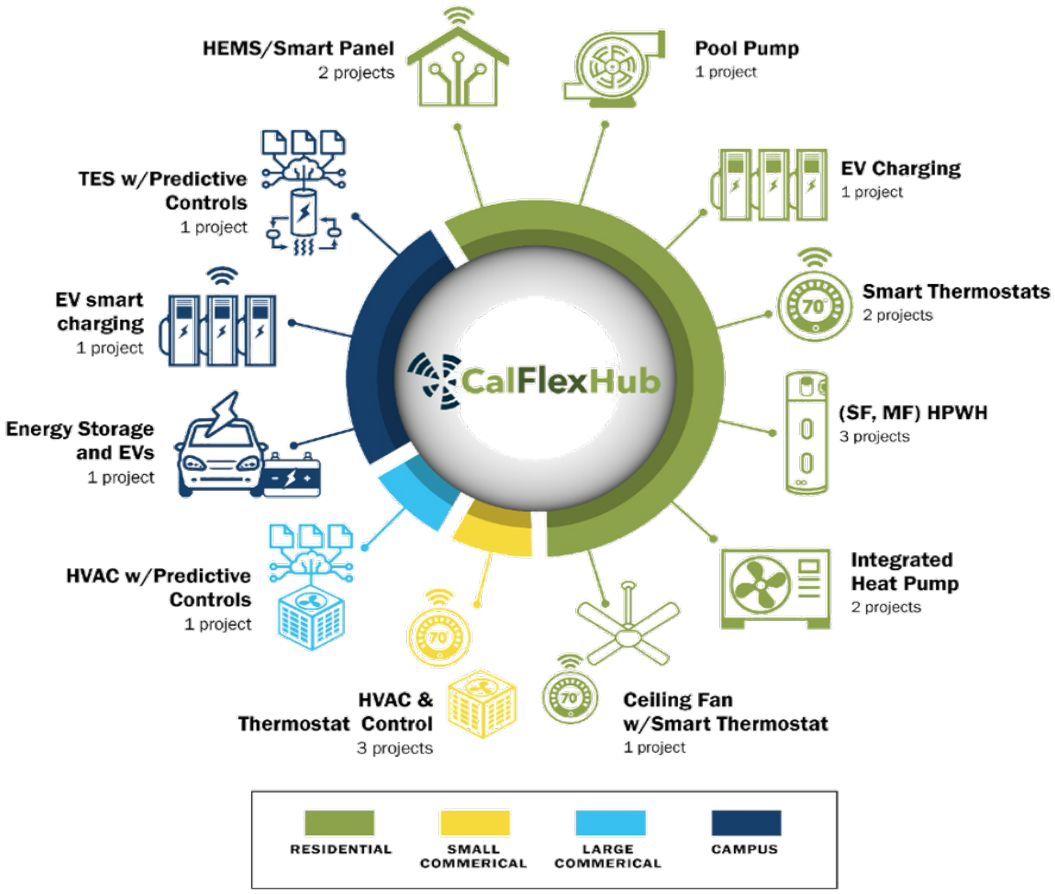
Overview

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

Many CalFlexHub check-in meetings were conducted during the first two quarters of 2024 and 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.
- Five selected projects specific to the SCE collaboration effort have begun during Q1 and Q2 of 2024. LBNL continues to coordinate refinement/updates of each of the projects' scopes and plans. These projects include the following:

  Project #1: Elexity Model Predictive Control

  Objectives:

  - 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.

  The project team leveraged an AI developer partner to approach two demonstration sites for recruitment with one site successfully confirmed. The team worked towards design/implementation of test price signals based on a recently developed 2-week continuously hourly varying price signals hosted on the MIDAS server along with a MIDAS connection guide.

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

  Objectives:

  - 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.

  The HPWH demo test units have been identified and procured at Irwindale test labs. Engagement with SCE Energy Education Centers was initiated with drafting of the training materials underway.

  Project #3: Gateway with Universal Devices

  Objective:

  - 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.

Building upon OpenADR Alliance's reference model, the project team has implemented an OpenADR 3.0 VEN and VTN in its gateway product that allows for creating and distributing local prices. The team has done research on a variety of cellular radio service and hardware options (and critically their costs) and identified one vendor as being most suitable at this time. Procurement of the needed hardware is complete and are fully integrated with the gateway.

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

Objectives:

- 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.

LBNL conducted a literature review to have a better understanding of the products and the market, for use as a basis for future interviews, then completed customer discovery interviews with five industry experts.

- LBNL completed five customer discovery interviews with participants ranging from Title 24 development consultants and system designers to CalTF members. Interviews provided insights such as: TES is already being adopted in indoor agricultural spaces, CalTF is working on new methodology to value load shifting and enable incentives for TES.

LBNL ran a PESTEL analysis and market analysis to identify key archetypes of thermal energy storage systems for use in the modeling effort. LBNL has analyzed the LBNL-Load dataset from CPUC DR Potential Study Phase 4 to quantify building sectors with load most appropriate for thermal energy storage deployments.

- The completed PESTEL analysis describes the macro-scale business environment for TES and LBNL is compiling that information into a final report. LBNL also reviewed architectures of different TES systems currently in the market, creating knowledge of different architectures to use in the upcoming simulation study.

Project #5: Price-response Business Models

Objectives:

- 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.

LBNL briefed SCE on CEC CFH Task 2 activities, identified initial common research interest in business models around dynamic pricing and load flexibility, and drafted an initial project abstract for SCE to review.

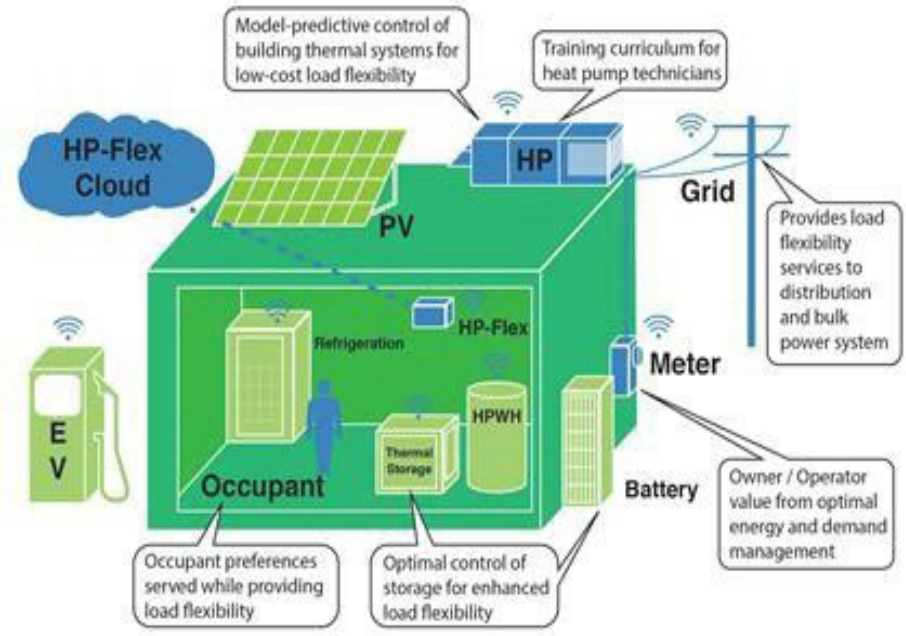
Next Steps

LBNL and SCE will continue their monthly coordination and refinement of the specified sub-project scopes listed above and finalize the desired scope of work and research outcomes through Q3 2024. Deliverables including project check-in/completion meetings, Technical Advisory Committee updates, and preliminary data reporting, are ongoing. The overall CalFlexHub Project at Lawrence Berkeley National Lab along with SCE advisory and project participation is scheduled to continue through 2025.

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.

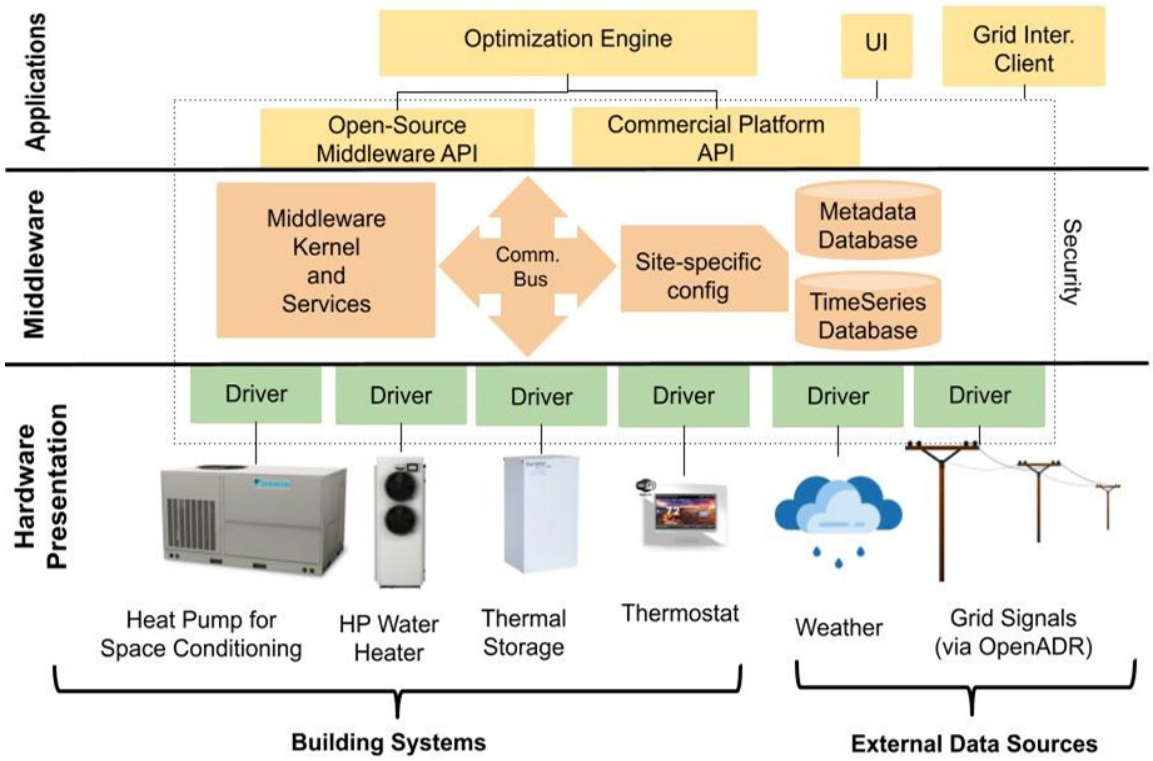
The project was funded under the EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer 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

Update meeting was conducted in Q2 2024, and preliminary results shared to SCE stakeholders. Software platform developed is now used across multiple projects and designed to easily port algorithms to commercial partners platforms.



HP-Flex: Middleware Software Platform Framework

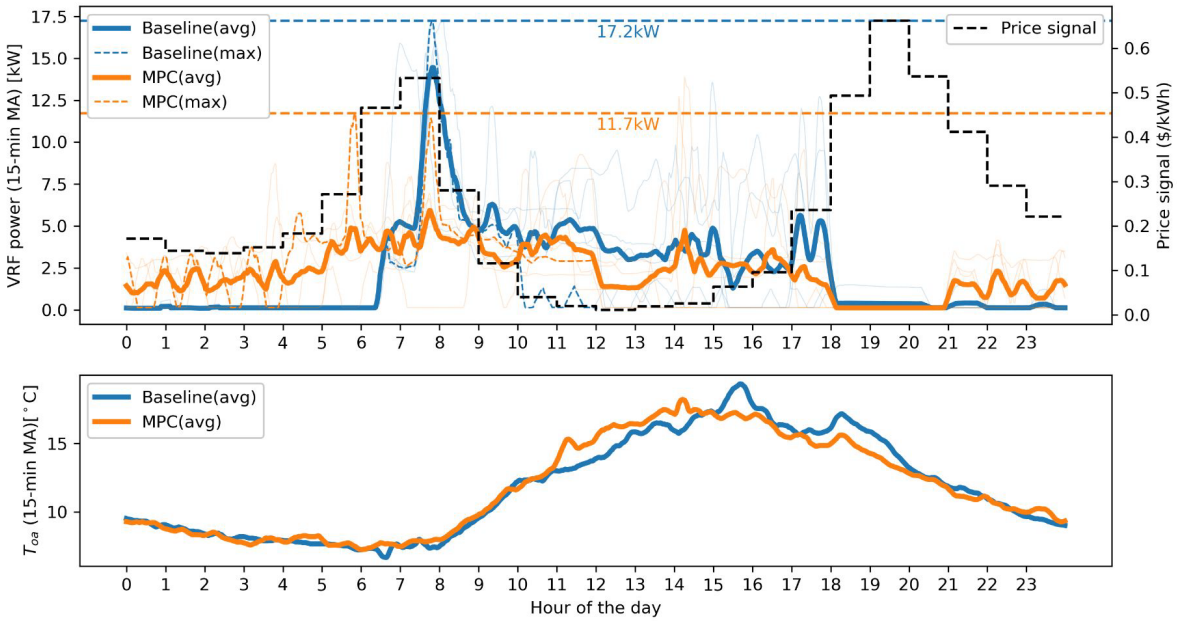
Preliminary field results (from other projects, not HP-Flex scope of field sites) include:

UC Davis Office

Baseline: Observations of significant peak in load.

MPC: Starts heating earlier then has reduced load at peak times.

- Peak demand reduction of 30% (17.2 -> 11.7 kW)
- Cost savings of ~3%, (no demand charge & minimum overlap morning peak price & occupied times)



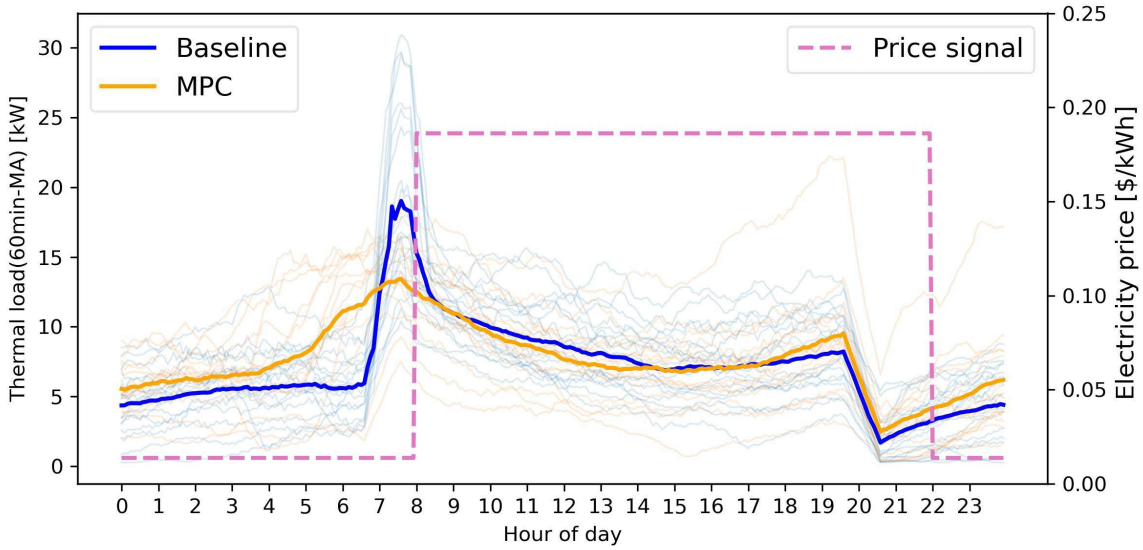
UC Davis Office: Load Comparisons of MPC and Baseline

NY Small Building

Baseline: Significant peaks in load and natural gas (NG) use.

MPC: Starts heating earlier, then has reduced load at peak times.

- HVAC load shift of 23% and cost savings of 27%
- MPC provides further NG reductions and energy savings in a dual-fuel system.



NY Small Building: Thermal Load & Price Comparisons of MPC and Baseline

Project delays experienced due to equipment supply chain issues and contracting difficulties by the LBNL research team. LBNL is coordinating timeline and deliverables

updates with SCE, and updated project completion is now expected by end of 2025 with possible CEC contract extension.

Next Steps

LBNL and SCE will continue to coordinate on updating the project timeline and reviewing and finalizing interim testing results and deliverables. LBNL project team next steps include set up of five new sites leveraging lessons learned from UC Davis, testing hardware retrofit compared to software-only upgrade, testing the portability of open-source software to commercial partners, and testing longer series and other types of prices. The SCE team will work with the lab partners in the coming months.

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 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

Vendor selection efforts for the redesign of the lab to accommodate the latest changes needed were successful in Q2 2024, overcoming the first phase of the RFI and RFP which encountered delays. The competitive selection was made through requests for proposal coordinated with Supply Chain Management.

Next Steps

Negotiation and finalization of contracting and onboarding expected to occur in Q3 2024. Project design phase is still expected to occur in Q3 – Q4 2024 as planned given the changes in the overall project schedule with SCE facilities team, and the TTC team is on track to finalize the design phase by the end of 2024. The overall construction phase for complete functional test chamber completion is expected by Q4 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

An initial 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.

Education decal can be branded and placed on any switch plate

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 (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 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.

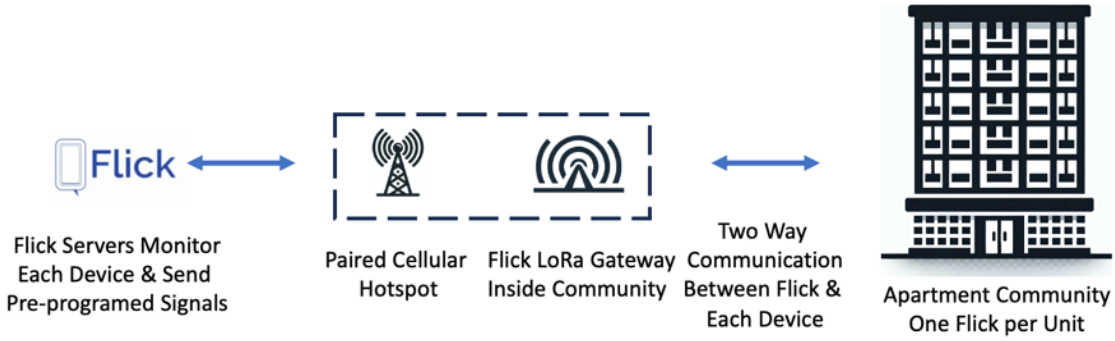
Collaboration

To implement the research study, SCE executed a service contract with an evaluation contractor with Flick Power as the technology. 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

For the initial phase of the field study, twenty-five devices in the first deployment 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 operational capability in a second-

generation device as a closed loop system where the Flick team manages all communications with devices, gateways, and its servers. This closed loop network ensures Flick does not need to rely on end-user or property level Wi-Fi, which is virtually non-existent in multi-family and affordable housing communities.



Flick's Closed Loop Communication System

Flick also developed an approach to use LoRaWAN, 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 is connected to Flick's LoRa gateway, which then communicates with Flick's backend servers. This will improve communications reliability in field tests.

Informed by data gathered during the first beta deployment, resident surveys, and input from property managers, steps have been taken to translate objectives and load analysis tasks into three sites of multi-resident and multifamily housing in San Bernardino and Los Angeles Counties.

Next Steps

This first phase of the study is still ongoing and will include installation of second-generation devices to replace the inoperative devices, and test & control surveying in Q3 2024. Activities and deliverables expected for Q4 2024 include a comprehensive survey report and load impact report.

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3. Projects Completed Q1 – Q2 2024

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

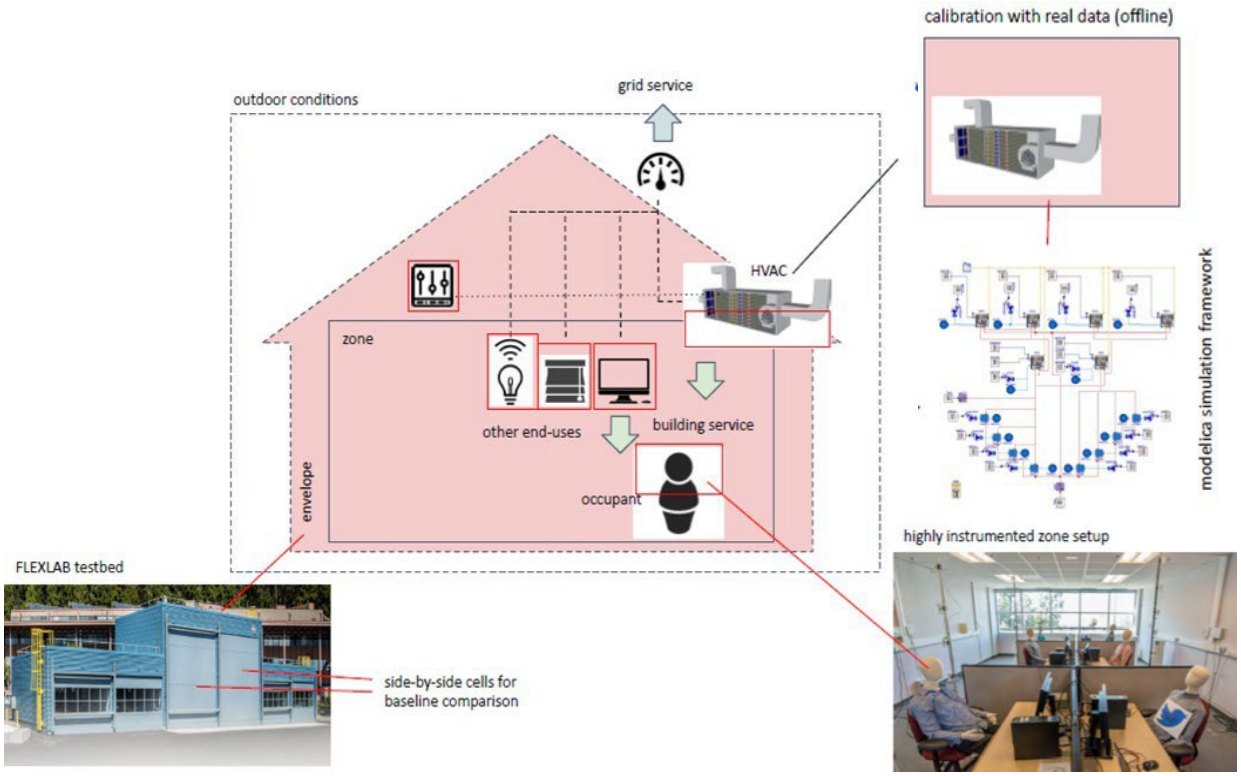
Overview

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 DOE-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 is 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 cost share of $300,000 to supplement the DOE's grant.

This DOE project at LBNL generated 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 measures 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

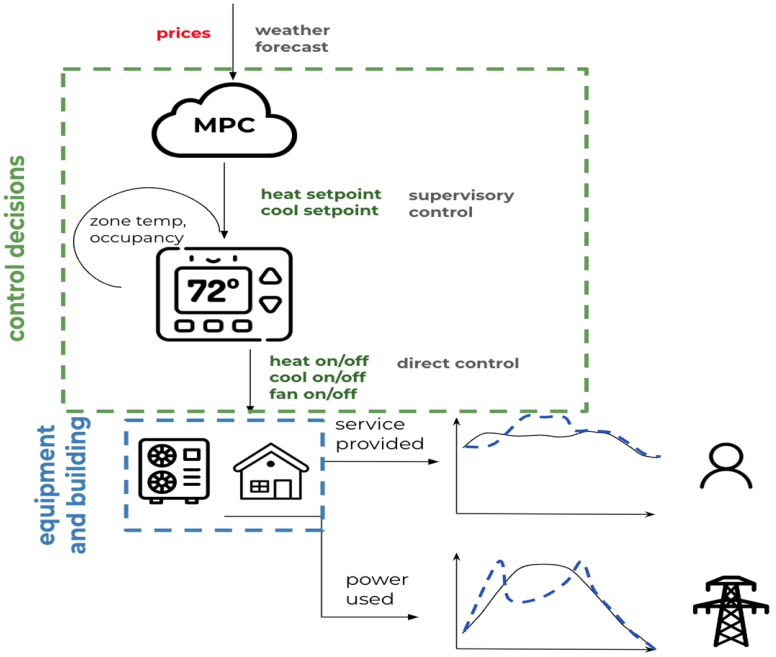
The HIL software infrastructure architecture at LBNL has the following responsibilities:

- **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?



Hardware-in-the-Loop (HIL) Predictive Controls Approach

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 a contract with LBNL funded by the DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DOE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019." SCE worked with LBNL as a co-funding partner with the DOE and as reviewer of the work. SCE engaged other industry stakeholders and subject matter experts that serve on the Technical Advisory Committee (TAC) establishing direction for the research team and ensuring that SCE is receiving the learnings from the project that are most valuable to its customers. In addition to the TAC meetings, SCE received timely updates for ongoing consultation and access to the reports and deliverables produced for the DOE BTO contract advisors.

Results/Status

SCE confirmed receipt and acceptance of all project deliverables through Q1 - Q2 2024 and received a closeout meeting in Q2 2024. From the final presentation, LBNL indicated that three rounds of tests yielded a comprehensive understanding of challenges and solutions in FLEXLAB HIL experimentation. From the experiments, the team garnered insights and identified valuable lessons of essential considerations for establishing HIL tests:

- HIL experiments using the entire building as "hardware" introduces more complexity than the ones involving equipment, given the added degrees of freedom and factors to account for, such as building type and characteristics (use, envelope), internal loads, HVAC system, HVAC and lighting control. All these elements need to be defined at the very beginning of the experiment to ensure the tests accurately reflect a typical building found in the field.
- Constructing and operating HIL setups, particularly those involving thermal interfaces between hardware and software, can pose significant challenges that merit pre-planning. For example, during the second test, achieving synchronization required alignment of the supply temperature of the actual AHU with corresponding variable in the RTU-HP model.

- Some types of equipment use serial communication protocols such as Modbus RTU28 or BACnet over MS/TP29 which severely limit query frequency allowed and becomes a serious issue when the hardware needs to synchronize its operation with the HIL model. Several cases were encountered where hardware using these protocols would not respond to high frequency data queries, thus limiting the ability to read or write information to the controlled systems.

Completed deliverables provided to SCE include:

- Creation and dissemination of Modelica simulation models of FLEXLAB at both component and system levels for potential use in upcoming studies, such as testing advanced control systems. Datasets, engineering designs, and publicly available models were leveraged to correctly parameterize the models. The calibrated FLEXLAB and HVAC system models are accessible to the public through an open-source repository– the Modelica Buildings Library, hosted and maintained by LBNL.
- Design of both a hardware and an open-source software toolchain to facilitate expedited testing within FLEXLAB. The hardware is engineered to tie into the hydronic plant or air-handler of any FLEXLAB cell, enabling future HIL experiments and thereby augmenting the experimental capabilities of FLEXLAB. The control and communication architecture leverages VOLTTRON, a middleware platform supported by DOE, that enables portability of advanced control algorithms between sites without significant reprogramming.

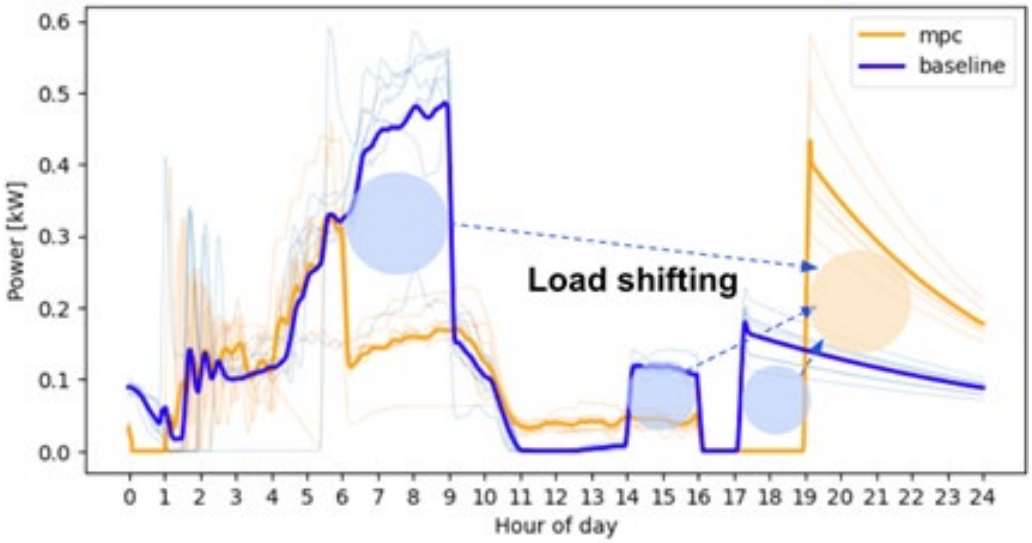
The HIL methodology was tested in practice using deployment of DF technologies in real-world scenarios. The control strategy developed in simulation and tested in FLEXLAB, was seamlessly tested in a building in New York and a second building in California. The algorithm consistently demonstrated its capability to shift more than 20% of the load in simulation, FLEXLAB, and in the field.

Second Test	**Baseline**	**MPC Ideal (% Difference)**	**MPC Hybrid (% Difference)**
Average daily energy consumption (kWh)	10.25 kWh	9.97 kWh (-2.8%)	10.41 kWh (1.6%)
Peak Load (kW)	3.0 kW	2.0 kW (-33%)	1.9 kW (-27%)
Thermal Comfort Impact (degree-hour)	2.60 °C-hr	2.23 °C-hr (-14.2%)	1.61 °C-hr (-38.1%)
Cost Reduction ($)	$2.60	$2.00 (-24%)	$2.10 (-18%)

Hardware-in-the-Loop MPC Test Results

In the second test, both MPC algorithms (Ideal and Hybrid) exhibited effectiveness by lowering peak demand by ~30% within the peak price window and achieved ~20% reduction in HVAC energy costs. While these results modeled the optimal approach for demand and energy savings, thermal comfort impact was minimized in the HIL scenario approaches.

The figure below illustrates the power profiles for the baseline scenario and MPC scenario (Test 3). The MPC algorithm demonstrated the capability to predict thermal loads and strategically discharge the TES, thereby shifting the building load from the morning high-price period to the lower-price period at night. The TES lower state of charge at the day's end meant a more substantial overnight peak demand as the HVAC charged the TES in preparation for the next day. Despite the high evening peak, overall demand still decreased.



Power profiles (averaged across testing days) for Test 3

Next Steps

Although the project as originally chartered is now complete, SCE and LBNL will continue coordinating on any further technology transfer and information dissemination activities and sharing with flexibility stakeholders. The Final Report with full modeling outcomes from the different test scenarios is available at www.dret-ca.com/wp-content/uploads/2024/9/DR22.01-Hardware-in-the-Loop-Flexible Modeling-DOE.pdf.

4. Budget

The following table represents the total expenditures for SCE's 2023 - 2027 EM&T authorized budget as of July 30, 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 August 1, 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 2023 – 2027	
Authorized Budget	$25,743,335
Budget Spent to date	$5,753,499

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.