Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q3 – Q4 2022

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

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SOUTHERN CALIFORNIA EDISON
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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
AMI	Advanced Metering Infrastructure
API	Application Program Interface
ASHRAE	American Society of Heating and Air Conditioning Engineers
AT	Advanced Technology
AutoDR	Automated Demand Response
BAN	Building Area Network
BBI	Better Buildings Initiative
BCD	Business Customer Division
BE	Building Electrification
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BOD	Biochemical Oxygen Demand
BTO	Building Technology Office
C#	C Sharp language
C&S	Codes and Standards
CAISO	California Independent System Operator
CARE	California Alternate Rates for Energy
CALTCP	California Lighting Contractors Training Program
CASE	Codes and Standards Enhancement
CCS	Conditioned Crawl Spaces
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
CZ	Climate Zone
D.	Decision (CPUC)
DAC	Disadvantaged Community
DER	Distributed Energy Resource
DOE	Department of Energy
DR	Demand Response
DRAS	Demand Response Automation Server
DRLIMFH	Deep Retrofits in Low-Income Multi-Family Housing
DRMEC	Demand Response Measurement and Evaluation Committee
DRMS	Demand Response Management System
DRRC	Demand Response Research Center
DSM	Demand-Side Management
EDF	Environmental Defense Fund
EE	Energy Efficiency
EEC	Energy Education Center
EERP	Energy Efficient Retrofit Packages
EM&T	Emerging Markets & Technology
EMCB	Energy Management Circuit Breaker
EMS	Energy Management System

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

PDR	Proxy Demand Response
PEV	Plug-In Electric Vehicle
PG&E	Pacific Gas and Electric
PLMA	Peak Load Management Alliance
PLS	Permanent Load Shift
PMS	Property Management System
PRP	Preferred Resource Pilot
PSPS	Public Safety Power Shutoffs
PTR	Peak Time Rebate
PV	Photovoltaic
QI/QM	Quality Installation/Quality Maintenance
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
TOU	Time of Use
TTC	Technology Test Center
UCOP	University of California – Office of the President
UL	Underwriters Laboratories
USGBC	U.S. Green Building Council
VCAC	Variable-Capacity Air Conditioning
VCHP	Variable-Capacity Heat Pump
VCRTU	Variable-Capacity Roof Top Unit
VEN	Virtual End Node
VNEM	Virtual Net Energy Metering
VRF	Variable Refrigerant Flow
VTN	Virtual Top Node
WW	Wastewater
WWTP	Wastewater Treatment Plant
XML	Extensible Markup Language
ZNE	Zero Net Energy

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1. Summary

Southern California Edison (SCE) submits this Q3-Q4 2022 semi-annual report in compliance with Ordering Paragraph (OP) 59 of the California Public Utilities Commission (CPUC) Demand Response Decision (D.) 12-04-045, dated April 30, 2012. That Decision directed SCE to submit a semi-annual report regarding its demand response (DR) Emerging Markets and Technology (EM&T) projects by March 31 and September 30 of each program year.

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

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

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

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

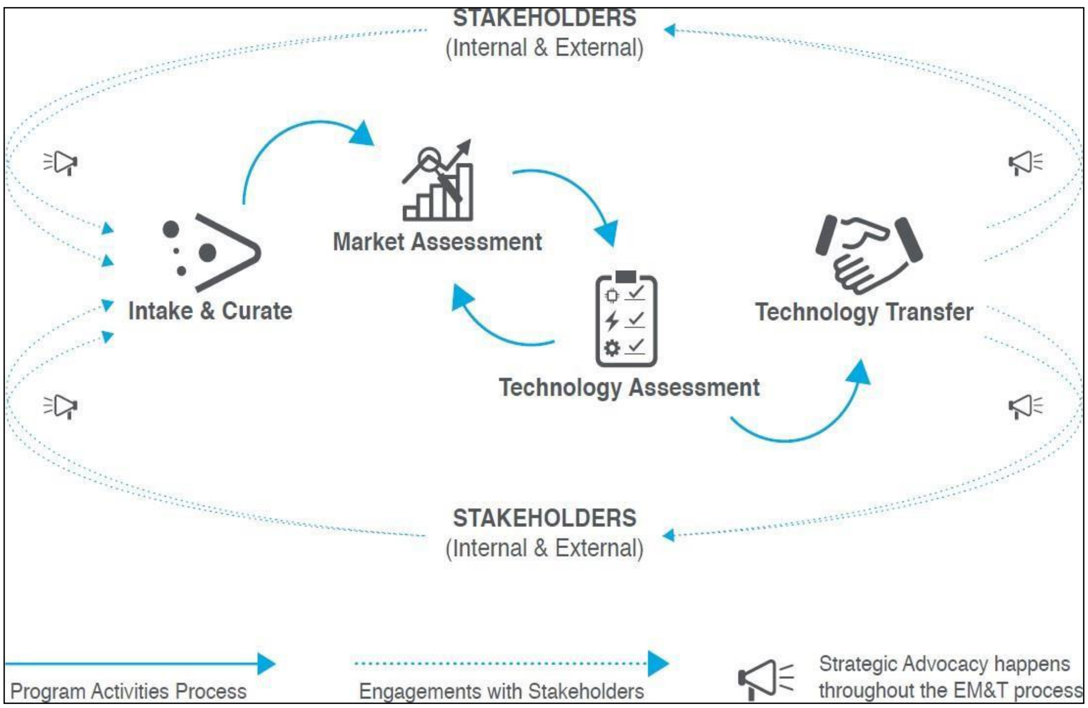
- Intake and Curation: Identifies studies, projects, or collaborations for inclusion in EM&T's portfolio and selects which ones to fund based on a well-informed understanding of the broader industry context.

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

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

- Technology Transfer: Advances DR-enabling technologies to the next step in the adoption process, including raising awareness, developing capabilities, and informing stakeholders during the early 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 of 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 completed, in progress, or initiated during the Q3-Q4 2022 time 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 Completed		
DR17.03	Demonstration of Affordable, Comfortable, and Grid Integrated ZNE Communities	Market Assessments Technology Assessments
DR19.05	Virtual Power Plant Projects	Market Assessments Technology Assessments
DR19.07	Measuring Builder Installed Electrical Loads	Market Assessments Technology Assessments
DR20.03	DR Technology Enhancements Using Dynamic Prices	Market Assessments Technology Assessments
In-Progress Projects		
DR18.09	Flexible DR Integration	Market Assessments Technology Assessments
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
DR21.01	DR-TTC Dynamic HVAC Test Chamber	Technology Assessments Technology Transfer
DR21.03	Dynamic Rate Pilot	Technology Assessments Technology Transfer
DR22.01	LBNL Hardware in the Loop Flexible Modeling DOE FOA-0002090	Market Assessments Technology Assessments
DR22.02	HP-flex: Next Generation Heat Pump Load Flexibility DR	Market Assessments Technology Assessments

EM&T Program Projects Investment Categories

SCE works collaboratively with the electric California Investor-Owned Utilities (IOUs), and with other DR research organizations, national laboratories, trade allies, and state agencies, to leverage the outcomes of their research of innovative technologies and software that could enable increased customer and stakeholder DR benefits. Many state and federally funded research studies in California are also reviewed for their opportunities for partnership funding and technology transfer into the EM&T portfolio. The EM&T program has successfully leveraged other research projects and activities funded from the California Energy Commission's Electric Program Investment Charge (EPIC) program, as well as the Department of Energy's Building Technology Office (BTO) and other state and federal research grant opportunities.

In accordance with the CPUC direction for the reporting of the DR EM&T program, this report covers SCE DR EM&T project activities during the timeframe between July 1, 2022 and December 31, 2022 for Q3 and Q4 of program year 2022.

2. Projects Completed Q3 – Q4 2022

DR17.03 Demonstration of Affordable, Comfortable, and Grid-Integrated ZNE Communities

Overview

The research goal of this project was to demonstrate and assess the advanced design and installation of advanced DER measures for all-electric Zero Net Energy homes within the multi-family housing sector. A secondary objective was to study how ZNE homes in this segment perform with solar and thermal storage and to develop strategies for effective DER integration with the local electric grid. This project included load management and load modifying end-use operation, along with energy efficient technologies such as smart air-conditioning controls and other end-use measures. Both demand response "shift" and flexibility capabilities were also assessed.

Architectural Rendering of ZNE MF housing

Project outcomes offered guidance for the development of the next iteration of buildings that will meet the future requirements of the Title 24 California Energy Code for OpenADR communications and flexible appliances. Outcomes from the project will enhance neighborhood planning tools and assistance to developers and builders engaged in constructing all-electric master communities interested in ZNE construction. These buildings will ultimately feature built-in demand response capabilities and support utility distribution system planning through updates of the T&D planning models for sizing transformers and circuits.

The property developer of this project, along with the Electric Power Research Institute (EPRI), installed an integrated all-electric measure package consisting of numerous all-electric end use technologies for both customer interest in health and sustainability and to enhance the desirability and comfort of the property:

- Induction cooktops
- Open ADR-connected, Application Program Interface (API)-controllable heat pump water heaters
- Heat pump clothes dryers
- Electric barbeque grills
- High-performance windows
- Variable refrigerant-flow heat pumps
- Network-connected smart thermostats with DR capabilities
- Ducts located in conditioned attic spaces
- Voice assistant-driven smart home energy management systems
- Smart intermittent ventilation systems
- Integrated smart electric load panels with built-in circuit energy monitoring
- Integrated grid distribution planning for ZNE
- Integrated DR controls to improve electric load shaping

This project additionally provided the developer and EPRI feedback on the implementation of voice-activated smart-speaker demand response control of the in-home technologies and grid-interactive heat pump water heaters.

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.

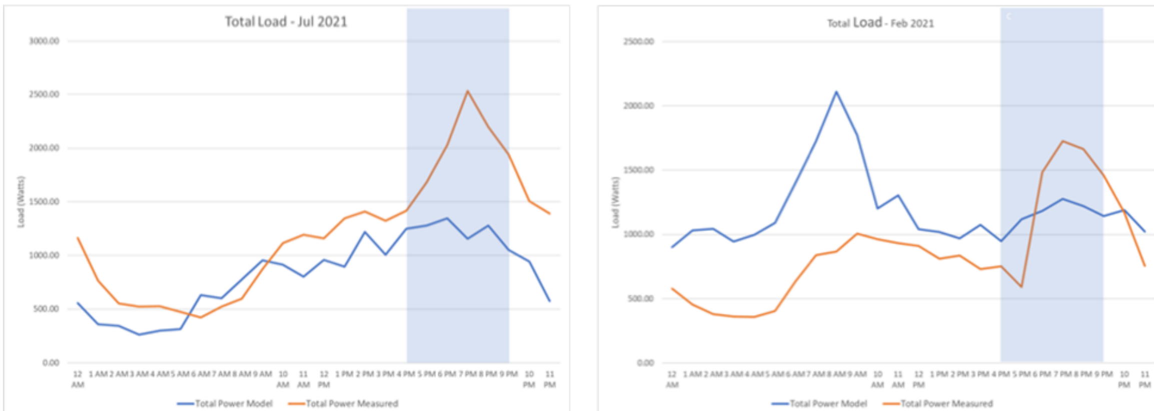
Collaboration

This project was a collaboration between SCE, EPRI, and the developer of the multi-family housing facility. SCE provided technical assistance with design, construction management, and demand response innovation review as well as planning and monitoring assistance and site installation oversight of the advanced technologies.

Results/Status

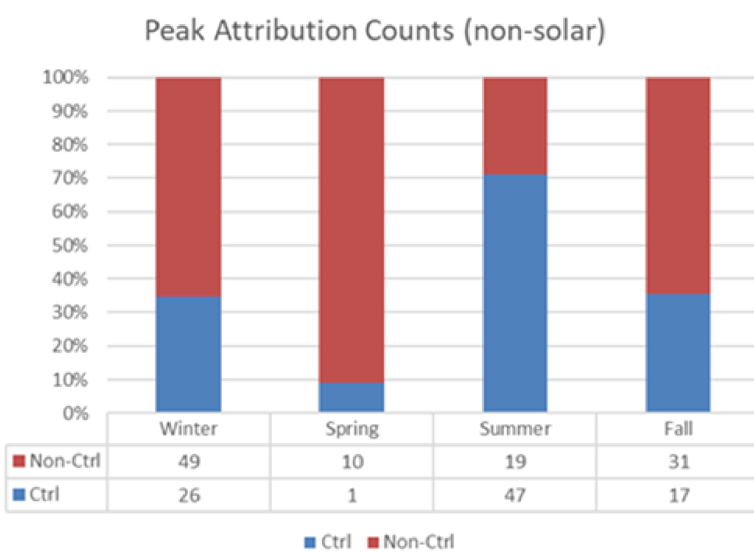
This community of 44 multifamily residences distributed over 8 buildings is now fully occupied. For the purposes of the study, 28 homes were commissioned with circuit-level load monitoring and 16 of those 28 provided reliable data spanning at least a year. Energy performance from two major end-uses, HVAC and water heating (WH), were assessed for their demand-response end-use potential and then evaluated to provide the community-scale DR potential.

Analysis of the residence (living-unit) level loads indicate that the non-coincident peaks in load shapes were largely driven by HVAC and appliance usage in summer and winter, compared to the EPRI total power models. The HVAC was all-electric.



Load shapes for summer and winter at the living-unit level

The peak loads in the community are seasonally driven (which is consistent with the energy models) by "controllable" loads (e.g., HVAC and WH). The summer share of the controllable peak loads is significantly higher than other seasons indicating a significant increase in summer load, with high energy efficiency providing mitigated peaking behaviors in other seasons.



Peak Attribution Counts by controllable and non-controllable loads

Preliminary analysis of electrical peaks measured in hourly intervals per season and distinguished between those attributable to controllable loads vs. non-controllable loads revealed the DR potential for the overall community load is 67.1 kW in Summer and 53.2 kW in Winter, representing about 35% of the overall community load for each season and assuming full community DR program participation.

Further assessment of peak load attribution, with and without solar PV, found that the Fall season presents another DR load impact opportunity of at least 30% of peak driven by controllable loads.

However, challenges in automating the DR implementation prevented the dispatch of the load reductions during the project. The proprietary Application Programming Interfaces (API) used by the HVAC and heat pump water heaters did not effectively integrate with the site’s 3rd-party DR management systems. The lack of 3rd-party APIs for energy management by the manufacturers and low participation from this market-rate housing segment calls for future investigation of novel approaches that improve 3rd-party partnership and customer engagement to help fully realize the DR potential of the electric end-uses reviewed.

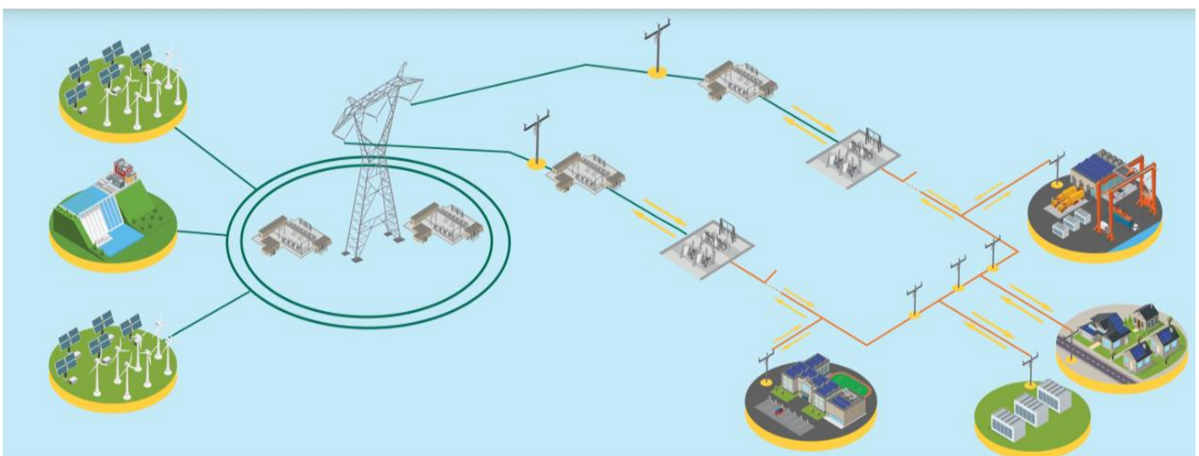
Next Steps

Comprehensive analysis of the end-use load data from this community has been completed, including insights on challenges and opportunities for programmatic DR implementation in all-electric ZNE communities. A final report was drafted during Q4 2022, and after review and final approval, the report will be made available on the DRET website and on the website of the project lead, EPRI, by early Q2 2023.

DR19.05 Virtual Power Plant Project

Overview

Depending on the specific application and use case, Virtual Power Plants (VPPs) can accomplish a wide range of tasks to aggregate distributed energy resources such as solar panels, distributed generation, and battery storage, in order to monitor, forecast, optimize, and trade their power. Distributed VPPs can work in concert with centralized, utility-scale renewables to ramp up and down either the power generation and/or power consumption of controllable DER units through third party services. The VPP network not only helps stabilize the local power grid but also creates the preconditions for integrating renewable energy into the markets. By aggregating the operation of many decentralized units, a VPP can deliver the same service and redundancy and subsequently trade on the same markets as large central power plants or industrial consumers.



Current Grid Architecture Example with Distributed Energy Resources

The VPP network in this project utilized residential behind-the-meter (BTM) battery systems to demonstrate the ability to provide pre-scheduled demand response grid services. The VPP aggregator enrolled 200-500 customers from a population of 1,000 customers with PV-paired battery systems. Customers with batteries typically use the systems for TOU rate arbitrage and emergency backup services when the systems are not providing demand response grid services. For the pilot, SCE executed demand response events by dispatching signals to the VPP integrator via the SCE demand response automation system (DRAS). Customers were then compensated for their participation and were able to override events.

This project was overseen by the Demand Response Operations Pilots group, and a portion of the M&V cost was 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

The SCE EM&T Program role was to provide supplemental funding for the SCE contractor overseeing the measurement and verification process for the VPP project team. Their scope was to identify potential use cases for demand response grid services from the PV-paired battery storage systems involving management of SCE system demand on a day-ahead basis, management of local distribution system demand on a day-ahead basis, and SCE system or local distribution system demand management on a day-of or emergency basis. The potential use cases SCE tested will provide data on future demand impacts in kW per dispatched battery system.

SCE VPP Project had the following research objectives for the pilot:

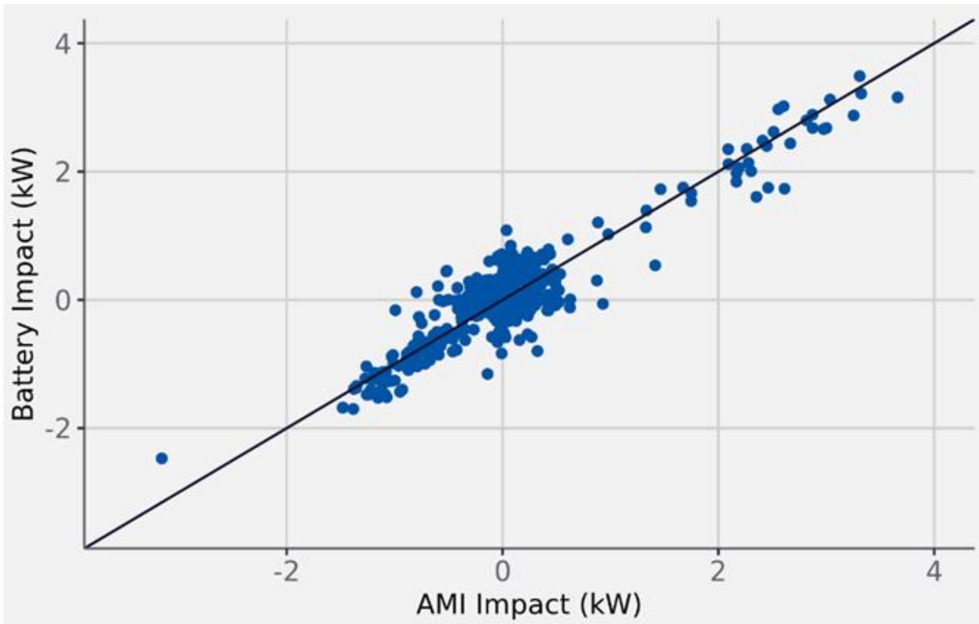
1. Can the third-party VPP aggregator provide the grid services in the required amount and when the services are needed?
2. Does the operational process to dispatch BTM batteries work as expected?
3. What is the persistence of savings during events?
4. Which of the potential use cases do the pilot outcomes best support?
5. What MW capacity does this pilot provide and what are the technical performance characteristics of PV-paired battery systems?
6. How integrated are Sunrun controlled PV-paired battery systems with SCE's demand response management system?

Results/Status

A total of 275 eligible customers participated in the pilot. The test procedure involved seven demand response scenarios (use cases) with different start times and durations, each partially overlapping with the 4 p.m. to 9 p.m. on-peak window, during which the customer's batteries are programmed to discharge daily. The evaluation estimated the electricity demand impacts of the demand response at the utility customer's meter and analyzed the battery and solar PV system telemetry data to assess battery performance during demand response events.

VPP demand response event impacts were evaluated against a baseline of the demand of SCE residential customers not enrolled in the pilot (that is, nonparticipants). The VPP Pilot generated demand savings in most hours, except for the hour beginning (HB) at 5:00 p.m. VPP dispatched load reductions during HB 5:00 p.m. were not realized largely because batteries normally discharge most of their energy during this hour. Savings in other event hours averaged 0.62 kW per participant.

Researchers compared demand impact estimated using customer AMI meter data and battery telemetry data and found that the analyses produced remarkably similar demand impact estimates from both sources. In addition, the AMI meter and battery telemetry demand impact estimates were highly correlated (simple correlation coefficient=0.91). The accuracy of the VPP demand impact estimates based on analysis of battery telemetry data suggests such data can be used in future impact evaluations.



Battery Telemetry vs. AMI Impact Estimates

As residential batteries provide a limited amount of capacity since most SCE residential customers utilize their batteries to manage their TOU rate charges, the VPP pilot resulted in smaller average demand response impacts than expected. Future VPP projects will need to manage battery charging and discharging timing to optimize VPP performance during DR event periods.

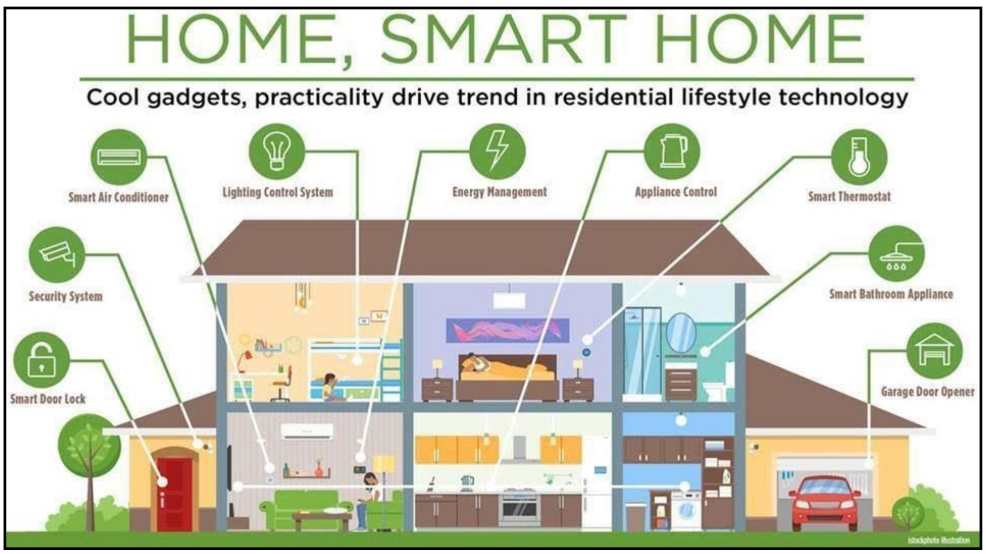
Next Steps

The engagement and support of the EM&T program for this project was limited to co-funding the verification study for assessing the load impacts of the Pilot. The VPP Final Project Report will be available on the DRET Website in Q2 2023.

DR19.07 Measuring Builder Installed Electrical Loads

Overview

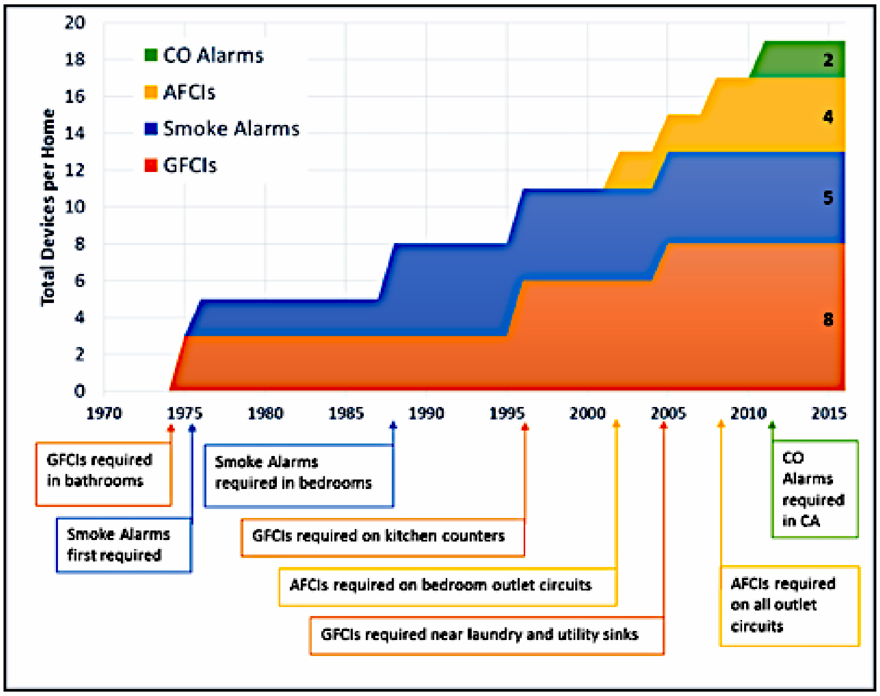
Today's home builders and developers mostly select and install permanent (or "hard-wired") electrical appliances and components in new homes based on cost and market desirability. The minimum energy efficiencies for common appliances — air conditioners, heat pumps, heat pump water heaters, pool pumps, refrigerators, etc. — are determined by the local and state codes and standards, so a home builder's impact on improving energy consumption is likely to be modest. At the same time, new homes — and especially new, "smart" homes — are outfitted with a second group of devices. This category includes EV chargers, communications infrastructure, batteries, and security equipment. These devices communicate through various protocols to both in-home hubs and to the cloud. The figure below illustrates just a few of the smart home technologies appearing in new homes.



Smart Home Technologies Illustration

These "smart" devices provide diverse services and are interconnected in the home. They are also connected in the sense that the builder/developer is responsible for their selection, installation, and commissioning. Builders and clients are challenged in making rational trade-offs because little consistent information is available on costs, features of energy and power consumption, and demand. In contrast, through its close connections with developers and builders, SCE has a unique opportunity to influence decisions regarding equipment selection in future smart homes through information and incentives. The first step, however, is to understand the "builder-installed" loads.

Anecdotal data from previous research in this topic suggests that builder-installed electrical loads could be contributing as much as 1,300 kWh/year in total power usage in new homes, even before occupants move in. No information is currently available to assess how this impacts load shape or demand flexibility opportunities. SCE developed this first phase of research because this aspect of residential "standby" energy use has not yet been carefully studied. As new homes receive PV, smart inverters, energy storage, and smart car-charging systems, the impacts of these loads could increase.



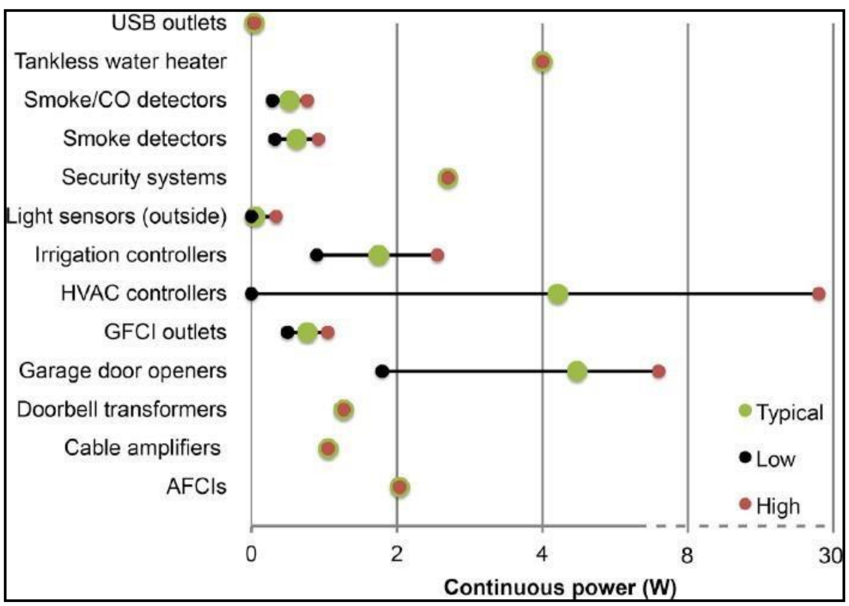
Growth in Code-Required Systems in New Homes

The research objectives of this project were:

- Examine opportunities for load management (shift and/or shed) of new construction hard-wired loads that could possibly be managed to reduce their small but growing impact on future overall residential energy load shapes and ultimately GHG emissions.
- Develop anticipated new load shapes and energy use of new "smart homes" and all-electric homes with a focus on builder-installed equipment, such as EV chargers, smart inverters, and battery storage systems.
- Develop a comprehensive assessment to provide a technical forecast for the demand response potential of such smart homes.
- Help SCE identify opportunities for load shifting, demand response, and energy savings with the new home technologies.

The first step in the study was to collect data on electricity consumed by electrical equipment in newly constructed homes. The plan developed was to collect short-term, whole-house power measurements from new homes during a relatively short time period between completion of construction and move-in of the homeowner. The research team was to identify builder-installed electrical devices found in new, smart homes in California and other relevant locations. The team would review bills of materials and information about actual construction practices in new homes. Focus would be on non-standard appliances and devices (that is, not air conditioners, refrigerators, lights, etc.) and all-electric homes. The team would prepare a list of devices and their technical characteristics. This included estimating the power draw, load shapes, and energy consumption based on nameplate, laboratory measurements, and literature surveys.

The information would be assembled in the form of typical homes, with estimates of types of builder-installed devices, their power, load shape, and energy use. The focus would be less on conventional appliances and equipment (for example, air conditioners, water heaters, etc.) and more on products associated with "smart" homes. Thus, the main product would be a portfolio of typical homes, along with their energy characteristics, for the devices typically installed by the builder before the occupants move in. The focus would be on early-adopter configurations; however, some homes with a more modest collection of smart devices would also be included.



Summary of Typical Builder Installed Loads

In the second phase of the project, the research team planned to create a model of prototype home data that can hold builder-installed device data and perform simple calculations. This would include home information such as floor area, and device characteristics such as load shape and demand shifting opportunities. The team would create five "smart home" prototypes with builder-installed devices based on the bill of materials. The team would then calculate the contribution of the builder-installed devices to the home's power draw, energy consumption, and load shape. For a specific assessment of the demand response potential, the team would investigate the gross load impact of builder-installed devices, calculate the whole-house load shape for each prototype, and evaluate the load shifting potential of individual builder-installed devices, with an emphasis on dispatchable devices and possible interaction with either EV smart inverters or installed energy storage.

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

This project includes collaboration with internal SCE groups, including Emerging Technologies and the Business Customer Division. Stakeholders have an interest in finding demand responsive solutions for builders that will make the homes they construct less energy intensive while managing loads to minimize grid impacts.

The study was conducted with researchers located at the advanced buildings section of the LBNL facility, EPRI, and builders coordinated through SCE field services.

The project was co-funded by the SCE Emerging Technologies and Emerging Markets and Technology programs. Additionally, as a member of EPRI, SCE is also co-funding parallel research investments with other utilities and leveraging that research to assist in this study, but no other direct cost-sharing or co-funding with any other parties was enabled.

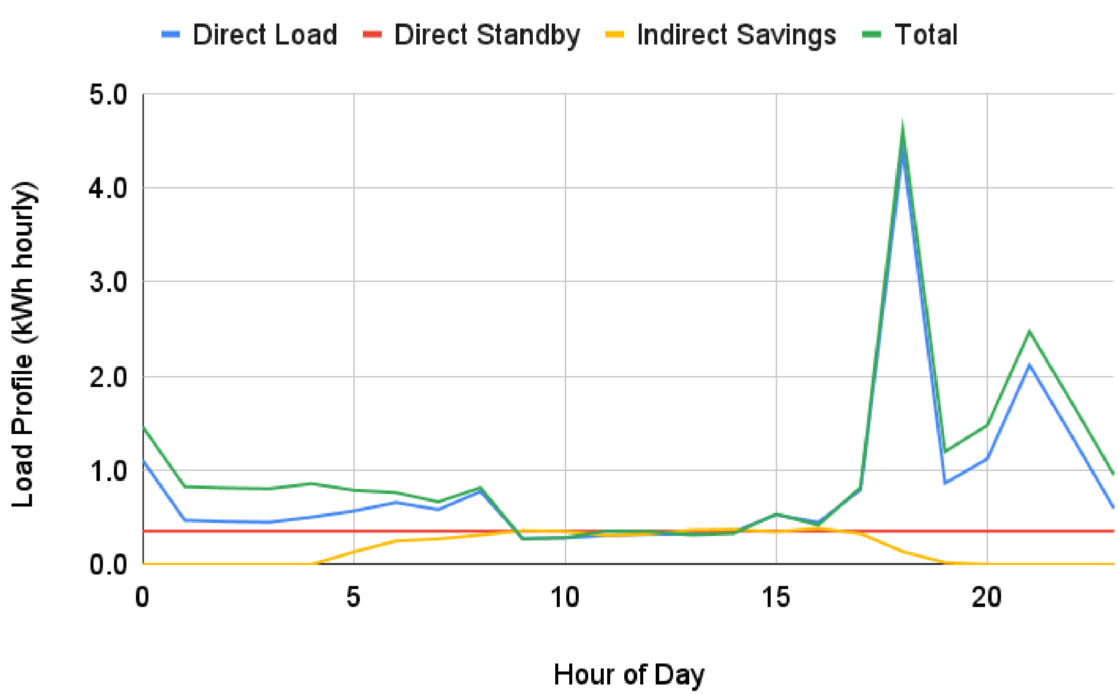
Results/Status

Due to COVID restrictions that prevented the field study of this project at the beginning of this work in 2021, LBNL limited their project scope to in-house research and laboratory bench testing. The team surveyed construction practices and compiled a list (or "library") of electrical appliances, equipment, and components that contractors often install. More than 100 devices were reviewed, but the project researchers ultimately reduced the list to the 38 that were most representative and non-repetitive and that had available data. The library included each product's energy and power consumption, the number of products in a typical home, and other relevant characteristics. Load shapes were also estimated. The focus was on capturing emerging trends of smart or connected devices. The library can be easily updated or modified.

In addition, LBNL conducted bench testing to categorize several loads' power scaling, standby consumption, and usage patterns. These loads included a Wi-Fi router, Wi-Fi mesh hub, irrigation controller, speaker system, and security monitor. Although the bench-tested loads were all plug loads, builders currently install them in the most high-end homes. Additional bench testing was conducted to characterize the standby consumption of safety devices, including smoke alarms, Carbon Monoxide (CO) alarms, and Ground Fault Circuit Interrupter (GFCI) and Arc Fault Current Interrupter (AFCI) outlets and breakers. On average, the constant-on consumption of these devices was between 0.5 watts (W) and 1W.

The technical modeling approach involved simulating energy and load shapes in six Southern California prototype new smart homes ranging from middle-income apartments to upscale houses. Each home was populated with models of the in-home devices appropriate to the size and climate of the prototype models.

Load impacts were estimated for each prototype home. This approach was useful because these prototype homes can be easily adapted as new information is gathered, regarding either products in the home or their electricity consumption. Laboratory measurements of many components were taken to better understand their behavior and to update the library. The results, shown in the figure below, show both standby loads as well as spikes in the evening due to modeling induction range and clothes dryer usage for comparison. While standby consumption did not vary significantly, the cumulative overall energy usage impact was nevertheless substantial, especially in large, upscale homes.



Aggregate Load Shapes for a Typical High-End, Single-Family Inland Home in Summer

Overall energy impacts ranged from roughly 13.1 kWh/day in a small home, to 19.7

kWh/day in a large, upscale house (with peak demands of 2.5 kW and 4.5 kW, respectively). In the upscale house, 36% of total energy consumption was due to standby and constant-on devices. Standby energy increased with floor area, but not with respect to climate (findings are summarized in the table below). This study found newer smart home standby consumption was up to three times greater than the 1,050 kWh/year from previous studies. With a few exceptions (such as stoves) standby electricity use was flat, therefore it did not substantially increase demand at any particular time. When combined, these constant consumptions could add up to, at most, 360 W. Thus, in home smart devices (excluding those covered by Title 24 and federal energy efficiency standards) in new smart homes may not significantly contribute to future peak demand challenges.

	Lowest Daily Consumption/ Savings (kWh/day)	Highest Daily Consumption/ Savings (kWh/day)	Peak Times
Direct Load	13.1	19.7	12 AM, 8 AM, 6 PM, 11 PM
Standby Consumption	2	9	Constant
Indirect Savings	0.3	4	4 PM

Summary of Energy Consumptions for the Six Typical Homes

The indirect load impacts are larger and more variable. Smart controls connected to window shades greatly reduce solar gain (and ultimately, cooling loads) by reliably closing during periods of high solar gain. The incremental benefits from such technologies will depend on the number of exposed windows and their orientation, combined with user behavior without the controls.

New home smart devices are responsible for a major fraction of the continuous (standby) energy consumption in new smart homes. The scenarios developed in this study showed that the continuous power consumption ranges from 100–360 W. For comparison, 360 W corresponds to roughly 45% of the electricity consumption of an average existing California residential customer. Even though electricity consumption of these devices is low on a per-unit basis, there are often many installations in each home. These laboratory studies demonstrated a wide variation in the standby power consumption of these devices.

Next Steps

The project closeout meeting informing stakeholders of the results of this project was completed in Q3 2022. The study found that the smart devices assessed by the project team provided very limited contribution to peak demand, and thus the BIEL measure category may not be a good candidate for Demand Response program/measure development. As a follow up to this work, new home devices may have potential for future Energy Efficiency research.

DR20.03 Demand Response Technology Enhancements Using Dynamic Prices

Overview

Demand response (DR) programs are important resources for keeping the electric grid reliable and efficient, deferring the need for increased peak generation capacity, reducing end use demand spikes and high loads to transmission and distribution systems, and providing societal economic and environmental benefits. SCE is committed to ensuring that customers have access to the most cost-effective demand response enabling technologies that are eligible for program incentives, thereby enabling customers to manage their energy costs and time of energy use.

The objective of this project was to study the continuing value in technologies that utilize dynamic pricing-based ADR and to provide a pathway for innovative emerging technologies that facilitate and increase customer participation in these programs and initiatives. The gaps in dynamic pricing-based ADR were to be identified and assessed. Further, identification of innovative emerging technologies, software, and market solutions for new models of DR program needs were to be identified.

The objectives were as follows:

- Identify applicable tariffs and their characteristics
- Evaluate how tariffs can be communicated to different customers using different communication technologies
- Establish the impacts of the emerging technologies (such as IoT, energy storage systems, etc.) in improving the ADR

A point of convergence of the research is that to be eligible for incentives from SCE and other utilities, most of the future DR resources need to be automated through ADR to allow them to be dispatchable and flexible, and the ADR protocol is now part of California Energy Commission's Title 24 new construction building codes.

CPUC-funded and related work at the LBNL Demand Response Research Center (DRRC) evaluated costs from DR automation programs and trends in the costs per kW of load-shed. Cost comparisons can only be made if there are standard methods of defining the costs for hardware, software, installation, configuration, and commissioning. The lowest cost sites are likely to be those with DR automation software embedded in controls. These lower costs may continue to become common as standardization in DR automation continues and vendors provide native DR in software. Also, various electrical end uses are often costly to automate or provide ADR-types of behavior due to their commercial or industrial facility type or high cost of acquisition. The following chart illustrates how the DRRC identified ADR potential across those customer sectors.

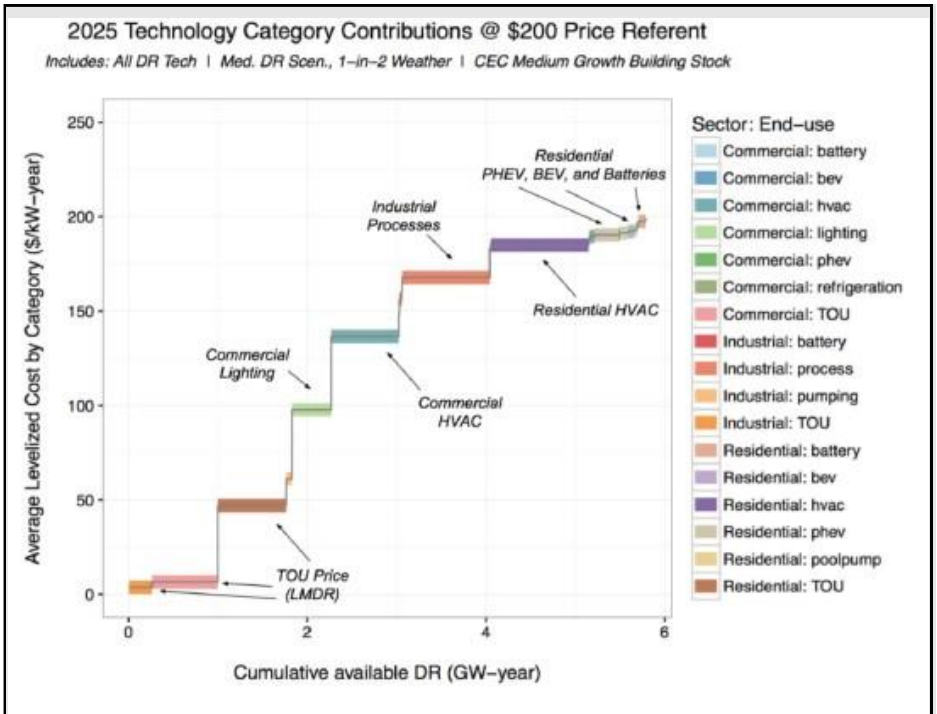


Figure 4: The 2025 technology category contributions below the $200/kW-year price referent. The average levelized costs for each technology category (y-axis) and their contributions to cumulative DR (GW-yr) are shown for the medium DR scenario, 1:2 weather year for all DR technologies.

Available DR Potential by End Use Technology

The DRRC's study also illustrated how market transformation has a synergistic impact with market barriers and a similar perspective should be explored for aggressively promoting a long-term commitment to DR in California. This may include new approaches such as upstream DR incentives for DR automation systems such as HVAC, lighting, or pumping systems. The DR automation market will become mainstream when control systems have communication hardware and software capabilities that can receive and send DR signals with minimal or no additional first costs. DR transformation of the controls market would enable lower cost DR with greater levels of participation.

SCE's goal for realizing California's DR potential over the next 10 years will be based on new models of DR programs that embrace the technology category contributions for end-uses that can provide "shift" and the integration of preferred resources such as distributed generation, storage, changes in codes and standards, and dynamic pricing structures. DR also has the potential to be a local resource for distribution system operations. Improving understanding of DR technical and market potential is critical as utilities explore how to overcome new challenges to integrate renewables and manage a more dynamic grid.

This study contributes to the understanding of strategies, software, systems, and advanced innovative enabling technologies and identifies new opportunities for DR resources through emerging market engagement, increased DR customer participation, performance, and improved uptake of DR automation protocols across a broader spectrum of high-tech industries and manufacturers.

The project has a set of five objectives (Task 1 — Task 5, below) that examine the technical capabilities of the portfolio of existing ADR and EM&T projects and evaluate opportunities for new pilot and program concepts. The LBNL team then worked with the SCE team to organize these ideas into a set of recommendations. These recommendations were based on the technical needs assessment and multi-year opportunity matrix that focus on both pre-commercial and near cost-effective solutions to enhance future SCE DR activities in the EM&T program.

Task 1. Assess Current and Potential Future SCE Tariffs for Data Elements

The purpose of this task is to identify the information that needs to be communicated to customers for their end-uses to effectively respond to new models of dynamic pricing. LBNL plans to evaluate existing tariffs and consider ways that new tariffs may provide the data elements for effective OpenADR communications messaging to end-uses that can participate in new models of demand response. This analysis will include:

- Smart Energy Program tariff
- Residential and (optionally) Small Business Time-of-Use tariff

This task characterizes tariffs in terms of the rate structure, periodicity, seasonality, potential frequency of adjustments or updates, possibilities for location-specific tariffs, and the number of customers in the various sectors and possible end-use classes at any location. Attention will be paid to details that affect the coordination of the messaging with both the need for customer action, or need for possible mitigation of renewable curtailment, and whether the rate is dependent on the direction of power flow at the meter. There will also be an assessment of the capabilities of the OpenADR messaging structure to provide effective messaging in either an embedded price structure at the customer device or a day-ahead hourly price model that can be transmitted machine to machine.

Task 2. Data Models and Data Communication Architectures

This task identifies the overall structure of relaying and communicating tariff information from SCE to individual customer end-uses via digital signals, building on the results of Task 1. The end-use loads of most interest include basic HVAC systems, water heaters, appliances, EVs, and battery storage. The opportunities for "shift" for these end-uses and in concert with the SCE dynamic rate designs will be assessed. This task will describe the existing and emerging device characteristics involved to receive and respond to digital communications, such as 1-way broadcast vs. 2-way systems, whether multiple communication channels are desirable and/or other features. The work will emphasize clarity on what parts of the system are the purview of the utility vs. those that are internal to the customer site, whether provided by an aggregator or manufacturer.

A key part of this task is to address not only the ideal future state in which all end uses can receive price and tariff data directly, but also the long transition time in which legacy devices need either external hardware control or external software that interacts with legacy device control mechanisms. Considerations for the data models will include machine-to-machine and cloud-to-machine architectures for a "whole building" or "total premise" approach. Of significant interest is the future scenario of messaging to the "premise" rather than through the end-use, with the sub-operational functions coordinated in a distributed manner through a central "hub" or "smart integrator" acting as the communication end node.

Task 3. Supporting Technologies and Communication Standards

This task is to review the landscape of existing communication technologies and see how they are suitable for use in the architecture that results from Task 2. This review will cover both physical layer protocols as well as the application layer protocols that they carry. Existing technology capabilities and characteristics will be described. The review of tariff communication from the utility grid to customer sites will consider current protocols which include OpenADR 2.0 versions A and B and will compare these with what is available in IEEE 2030.5 (SEP) using comparative studies already available through organizations such as the OpenADR Alliance. The task will also identify gaps in existing data model functionality that might require further investigation.

Other technologies that are suitable for communication within customer sites are examined, including Zigbee, Z-wave, and Wi-Fi. Important physical layer technologies for wide-area use externally include broadband Internet, cellular radio, FM radio, and within building energy management systems include Ethernet and Wi-Fi, Bluetooth, Zigbee, Z-Wave and more. The summary report describes which technologies can be used for core system operation for different applications. In some cases, there is a single technology for a particular purpose.

Task 4. Evaluate Cost Trends, Persistence, Storage, Internet of Things (IoT), Trends, and Information Technology Opportunities

To further examine emerging technologies for ADR and opportunities for "shift", the LBNL team will assess the emerging ADR technology trends, the opportunities for ADR in the Internet of Things, and how other information technology systems used in other markets (healthcare, financial, biotech), can help reduce the cost and improve the performance of automated DR systems. To drive broad adoption of automated DR systems, it is important to understand costs associated with their installation. The lowest cost sites are those with DR automation software embedded in controls. Since costs might be reduced over time by leveraging DR automation systems with other energy efficiency investments, they are explored as well.

This task also includes a review of OpenADR and storage system capabilities. This is a new and emerging opportunity for both "shift" resources as well as resiliency and possible arbitrage during dynamic pricing periods. This effort will emphasize the use of OpenADR with customer end-uses and will require a review of the DR signals, gateways, costs for automation, and emerging connectivity issues. The deliverable for this task will be a technical memo and a webinar with SCE staff to discuss the results.

Task 5. Develop Final Report and Recommendations

LBNL prepares a final report that summarizes the results of Tasks 1 through 4 and provide a set of short-term, mid-term, and long-range strategic recommendations for SCE on future opportunities for the EM&T program. This will include short-, medium-, and long-term activities to enhance DR programs over time, with recommendations for assessments of emerging technologies. The report will include a summary of all the project's technical memorandums and a summary of each task.

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

LBNL identifies new innovative technologies and software in the energy and consumer markets. SCE's EM&T program utilizes LBNL to assist with market solutions for advancement of SCE's DR initiatives to its customers. The EM&T program works to enable customer participation in SCE's DR programs by providing input to the Codes and Standards (C&S) program, which draws on research into customer preferences and the market potential for DR in California's new construction markets. In addition, to further enable and expand DR in California, SCE is involved in ongoing collaboration and research with other statewide agencies and third-party stakeholders. While the EM&T program is funding the project through a contract with EPRI, SCE is also leveraging its membership in EPRI with learnings and best practices from the parallel research by other EPRI utility members as a cost-sharing strategy.

Results/Status

The final project report has been completed. Researchers in this study identified innovative ways that customer end-uses can both receive price signals and respond—through rigorous technical factor review of control algorithms in the cloud, flexible loads, and customer-sited distributed energy resources. Results from the study culminated in recommendations for an overall communication architecture and a standard data model for representing price information, and validated how Price-Based Grid Coordination (PBGC) enables diverse communication paths and multiple locations for translating prices to functional controls.

A comprehensive review of SCE tariffs identified a catalogue of sixteen "tariff features" that are relevant to dynamic price communication. Analysis of the intersection of time-varying rates with these tariff features was complex but concluded in the general categories listed below.

Easily Adapted	Simple Adaptation	Difficult to Address	Not relevant
TOU, CPP RTP Sub-Tariffs Eligibility	Differential Buy/Sell Prices Voltage/Phase Discounts	Tiers Demand Charges Combined Tariffs Bill Limiter	Direct Load Control Rotating Outage Participation Reactive Power Fixed Charges

Tariff features as they intersect price communication for automated DR

In summary, the selection of which features to include in dynamic tariffs is critically important for the ease of communicating time-varying prices and for the ability of flexible loads and DER to use pricing signals to best serve customer and utility needs. The project team also reviewed high-level capabilities of three core protocols involved (OpenADR 2.0b, IEEE 2030.5, and CTA2045) as well as generic needs for their modification to support price communication. Both OpenADR and IEEE 2030.5 protocols can be updated and modernized to enable less data intensity and more transport efficiency for communicating hourly dynamic pricing signals.

Next Steps

The final project report will be available on the DRET Website in Q2 2023.

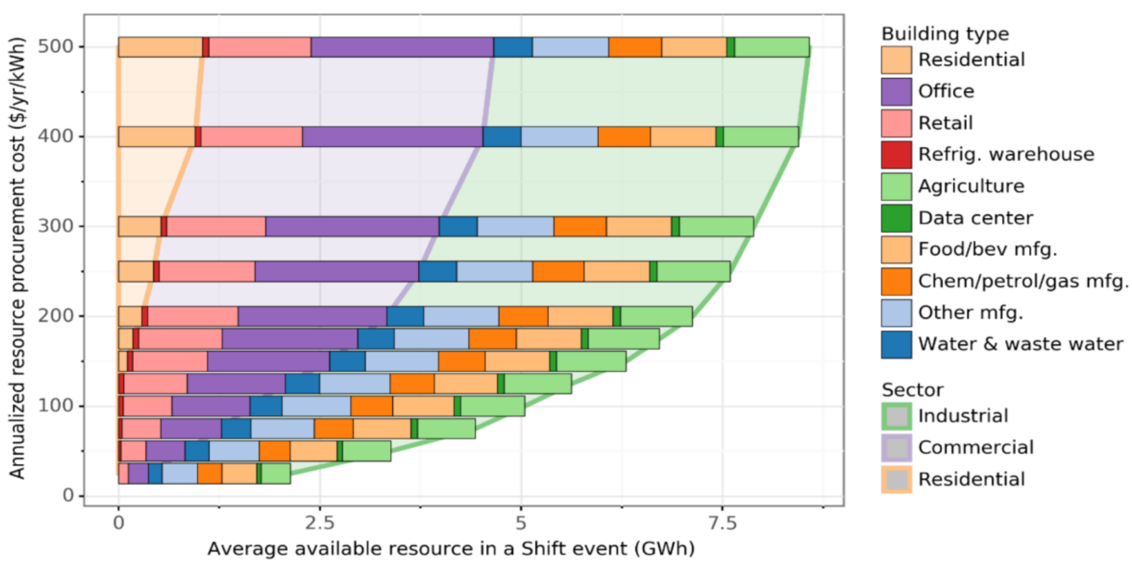
3. Projects Continued Q3 – Q4 2022

DR18.09 Flexible DR Integration

Overview

Demand response (DR) programs are important resources for keeping the electric grid reliable and efficient, deferring the need for increased peak generation capacity, reducing the impact of end use demand spikes and high loads on transmission and distribution systems, and providing societal economic and environmental benefits. SCE is committed to ensuring that customers have access to the most cost-effective demand response enabling technologies that are eligible for program incentives thereby enabling customers to manage their energy costs and time of energy use.

A series of studies performed the LBNL Demand Response Research Center (DRRC), known as the California Demand Response Potential Studies, have forecasted the DR market and technological potential in California (Alstone et al, 2017 and Gerke et al, 2020). These studies suggest that California might be able to double the DR flexibility potential provided by customer end-use loads and innovative technologies in the next ten years.



Opportunities for Demand Flexibility by Building Type and Sector (LBNL Study)

The objective of this project is to explore how to develop more demand flexibility from existing and future customer end use electrical loads. End-user electrical load flexibility applications and manufacturer capabilities for integration, while not an objective of this report, is the foundation on which dynamic pricing will depend on to succeed to enable that flexibility.

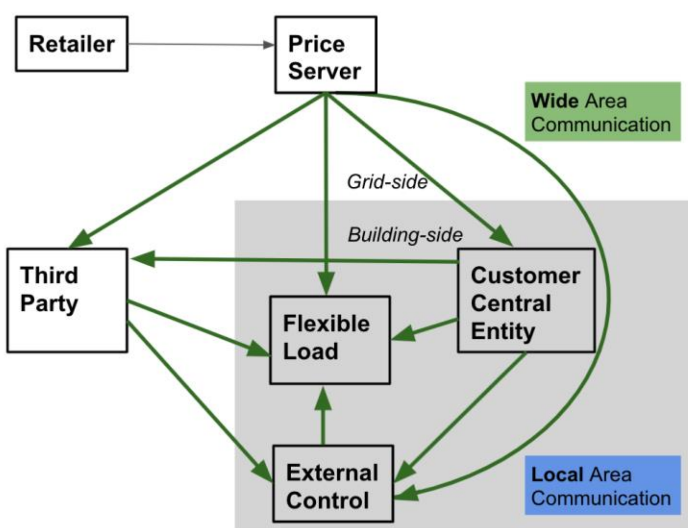
The project was funded under the EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of the emerging innovation and developments of new consumer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

To support development and implementation of demand flexibility opportunities in the SCE service area, the EM&T program in collaboration with EPRI enlisted Lawrence Berkeley National Laboratory (LBNL) to investigate the barriers to customer adoption and prepare a market assessment for SCE to follow in order to encourage innovation in this area. Thus, the purpose of this report is to identify enhancements of current technology to bring widespread implementation of demand flexibility to reduce grid congestion effectively as automated demand response objective.

Results/Status

To ensure customer eligibility and participation, most of the future DR resources will need to be automated through Automated Demand Response (ADR) to allow them to be dispatchable and flexible. California has made great strides in developing and promoting common standards for DR automation, which are critical for enabling low-cost pathways to DR and the evolution of the internet-of-things approaches that use onboard or built-in device connectivity to support DR, a potential avenue to technology-oriented DR market transformation.



Price-based Grid Coordination Communication Architecture

This project will outline a comprehensive vision for how to achieve dramatically increased electric load flexibility from customer loads. It addresses how to enable customers' equipment and systems to be able to receive and respond to dynamic price signals. There are three core elements to success:

- The energy retailer sets the price.
- The price is transmitted from the retailer to each flexible load or DER.
- The load uses the price with other information to decide how to respond and operate.

This study will emphasize the second and third topics in this list.

Key interim findings are as follows:

- An overall communication architecture, Price-Based Grid Coordination, enables diverse communication paths and multiple locations of translating prices to functional control and offers significant opportunities for flexibility while maximizing interoperability.
- There are numerous ways for devices to receive price signals and respond. These include intelligent control algorithms in the cloud, flexible loads themselves, and in central customer site control devices. All of these are now emerging.
- The new concept of a 'local price' of electricity facilitates maximum use of prices as the central mechanism for managing power distribution. Streaming prices to loads on a continuous basis to facilitate nimble use by sophisticated devices to benefit grid operators is highly practical. A standard way to represent price information (a data model) underpins the communication.
- There are several open and secure technology standards available today well-suited for price communication, but they can be improved and supplemented to make using them simpler and easier. Research and action by utilities can support implementation of each of these findings.

The path forward on developing load flexibility with dynamic pricing can be significantly enhanced through targeted research as summarized in the recommendations below. Items that need attention in the next year or two include:

- Updating and harmonizing the key communication protocols and creating universal price server discovery mechanisms for local and wide area networks.
- Identifying paths to make load flexibility available to all customers, including affordable methods for moderate-income households.
- Crafting comprehensive strategies for space conditioning and water heating to enable a rapid increase in the fraction of customers having at least one

substantial device that is price responsive.
- Prioritizing research on pumping and other process loads in industry, agriculture, and municipal services that are easily shiftable as with water storage.

Research goals for the two-to-five-year range include:

- Developing mechanisms to broadcast prices over the Internet generally, adapted to specific physical layer technologies (e.g., broadband access, 5G radio, satellite, etc.).
- Exploring ways to standardize and deploy device energy reporting to facilitate easy access to data on device energy use in response to pricing for utility customer and public policy needs.
- Developing solutions for managing capacity within customer sites and at the meter to reduce the costs for the electrification of previously non-electric loads, including EV charging.
- Using recent experience with the actual performance of price-responsive devices to inform updating quantification of load flexibility potentials.

Long-term research priorities include:

- Extending work on topics from the short- and mid-term that are particularly promising.
- Exploring the envelope of how much load flexibility can be obtained without notably impacting end-use load service delivery.
- Developing new and less costly thermal energy storage and related phase change materials for a wide range of applications.
- Extending price-response to other carriers of energy (e.g., district heating and cooling) and to multi-day and seasonal energy storage.

Next Steps

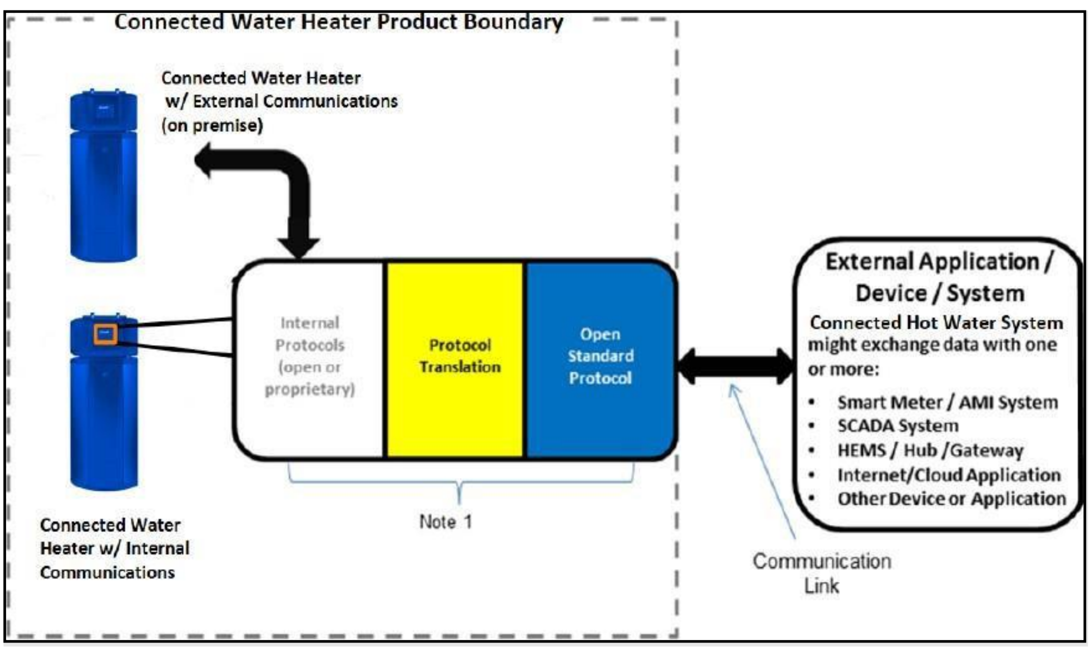
The research work is in the final phase and the report is in final review and will be posted to the DRET website in Q2 2023.

DR19.08 Grid Responsive Heat Pump Water Heater Study

Overview

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

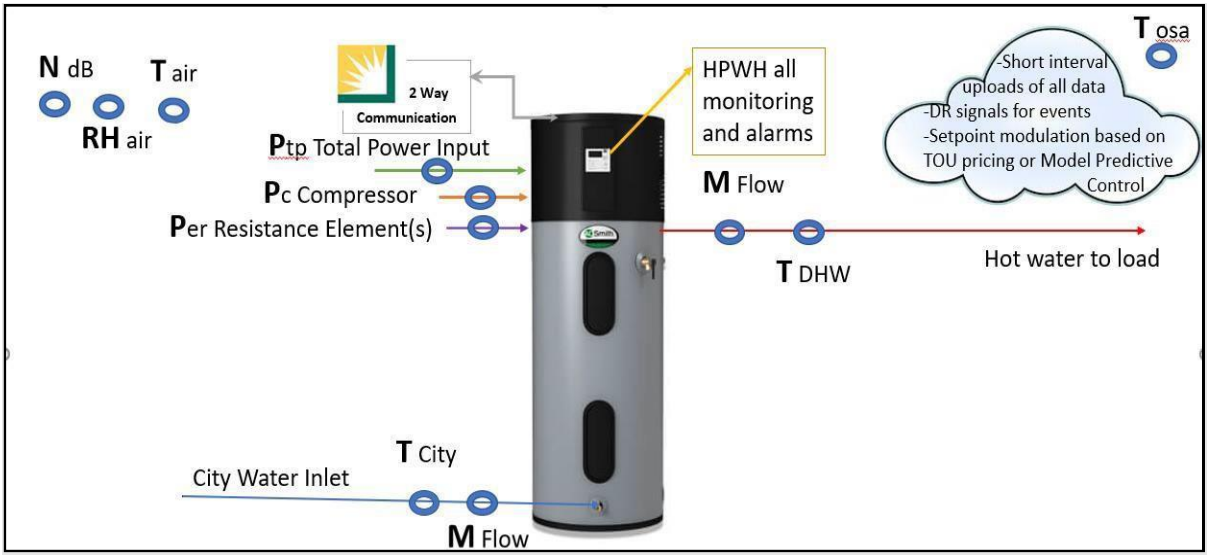
The study is in response to CPUC orders which stipulated: "Target installing local preset controls and/or digital communications technologies on 150 heat pump water heaters in each of PG&E and SCE's service territories." In response, SCE proposed the "SCE San Joaquin Valley Disadvantaged Communities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



Connected Water Heater Communications Architecture

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

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



Metering Diagram for HPWH Performance Testing

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

- Assist SCE in understanding integration of renewables and load dispatch as well as helping inform SCE if and how effectively a grid-responsive HPWH can provide flexible load control and hot water storage over various time frames. 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 time frames 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 analysis of the technical performance of HPWHs, including the technical capability of providing local grid impacts from grid responsive HPWHs as well as their performance in supplying hot water for the customers.
- In addition, SCE will gather information on customer experience, technical performance, grid benefits, and impacts of actual performance of the grid-responsive HPWHs as electric appliances in underserved communities.

All 12 homes selected have a garage for the HPWH and no recirculation system. The 12 homes are part of a larger SCE pilot to electrify 150 homes and reduce emissions within the SJV. The prime General Contractor (GC) and Community Energy Navigator (CEN) of the larger project will be responsible for the customer selection and the selection and installation of the grid-controlled HPWH and a proposed communication package to be used by SCE for the grid responsive signals. In order to minimize the risk of any failures of the technology that might occur at the customer's home, the HPWH controls and the grid-responsive communications technology will first be functionally tested in a laboratory environment prior to deployment in the homes.

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

Collaboration

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

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

Results/Status

Initial data collection revealed some issues with the instrumentation and data monitoring platform, however troubleshooting was conducted and completed by Q3 2022. Data collection and analysis/baseline characterization was conducted on an ongoing basis through Q4 of 2022.

Preliminary findings across all 12 sites for 4 months (September through December) indicate the following metrics:

- Avg Daily Energy Usage = 2.6 kWh/day
- Avg Daily Peak Demand = 3.4 kW
  - Avg % time above 1 kW = 0.6% (minimal usage time of heating elements)
- Avg Energy Factor = 2.8 (Rated UEFs were 3.88 and 3.45)

Avg Delivered Temperatures of 125.6 F
Avg Daily Hot Water Use = 358 gal/day
Avg Daily Hot Water Events = 66 events/day

Next Steps

The project team will complete baseline characterization analysis and continue to collect data at the remote customer sites. The project team will finalize the design of the demand response field tests and subsequently implement them in Q2 2023. The project is targeted for completion by Q4 2023.

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

Overview

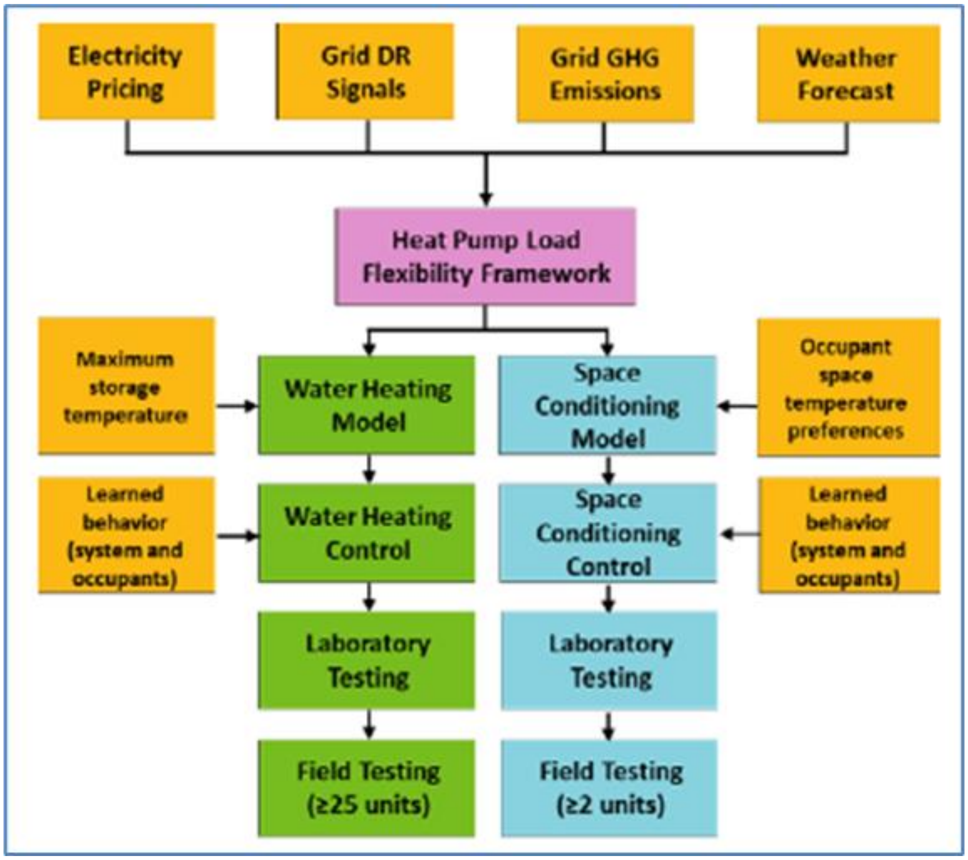
This CEC EPIC project will develop, test, and demonstrate an open-source framework for heat pump load flexibility controls that will be employed for both Advanced Water Heating Controls (AWHC) and Advanced Space Conditioning Controls (ASCC), with the goal of providing a common platform that can be leveraged 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).

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 (Figure 1). 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 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.

Heat pumps for space conditioning and water heating are currently controlled using rule-based logic to maintain a programmed water temperature or an indoor air temperature setpoint. While this approach is proven and robust for maintaining a user-defined setpoint, this type of control does not provide any flexibility for the timing of heat pump operation. For example, whenever the water or air setpoint is not satisfied, the rule-based control will run the heat pump until the setpoint is satisfied, regardless of the cost of electricity or the electrical grid GHG emissions rate.

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. 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.

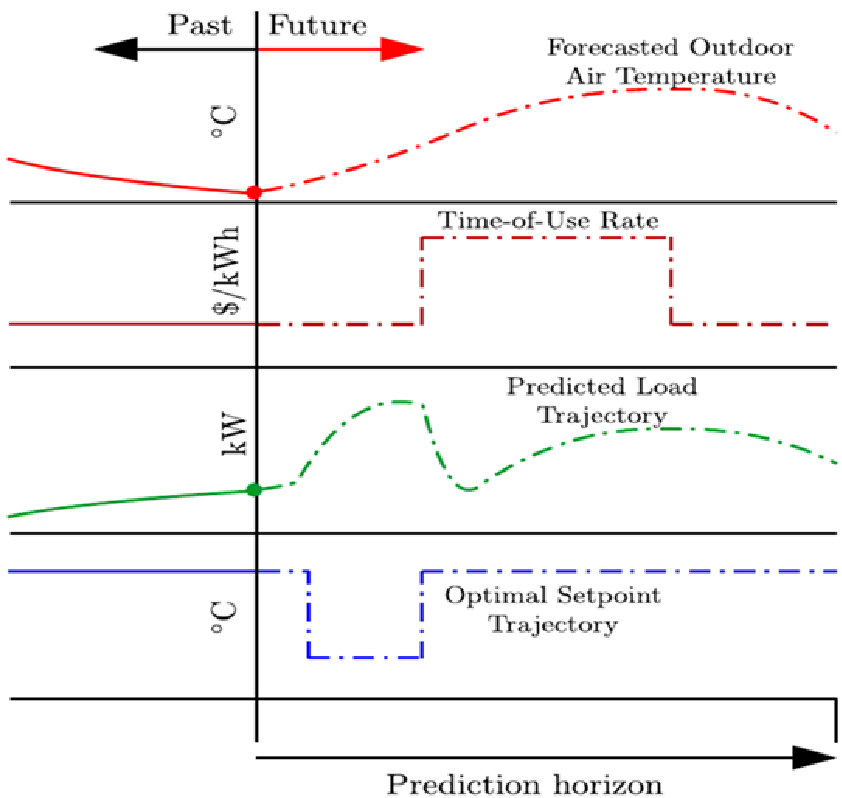


Overview of Project Design and Modeling

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.

The project vision is to develop AHWC and ASCC that are 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.



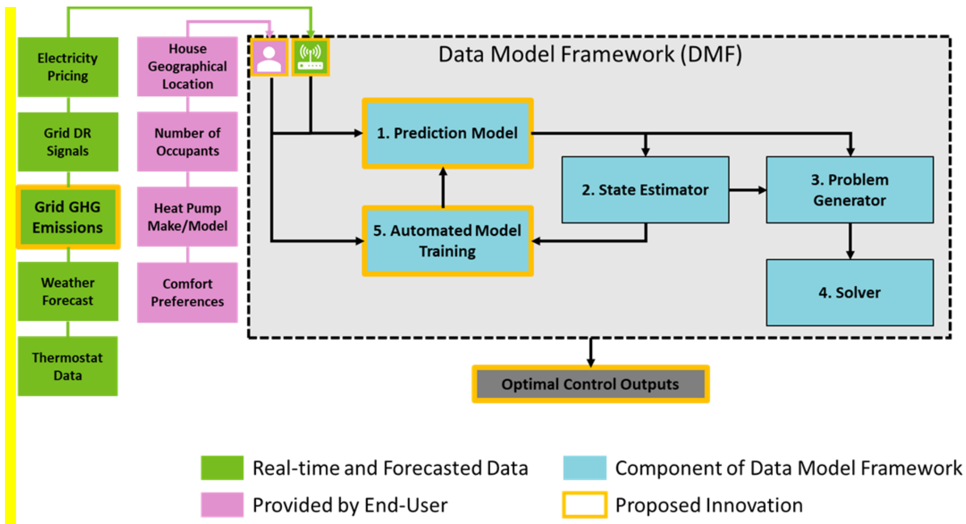
Modelling Predictive Control Optimization

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) in Figure 3 will replace the MPC subject matter expert and simplify the configuration, setup, and maintenance process.

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.

The project will 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 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 project 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.



Project Data Model Framework

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

Results/Status

Literature review for the market characterization study has identified key points and data gaps for the expert interviews. Development of AWHC is in progress and with lab testing to begin after cloud environment set up in Q2 2023. Simulation testing on AWHC approach is ongoing and has investigated different approaches to using electricity costs and GHG emissions in the optimization.

The validation testing of laboratory HPWH set-up is complete. MIDAS integration was added to the Data Model Framework retrieving time-of-use tariff information. Experimental testing of the HPWH in a climate-controlled chamber over a range of air and water temperatures has started. The ASCC laboratory benchtop test setup started Q4 2022.

Twenty-six households have been recruited for project field demonstrations. Baseline surveys for water heating and space conditioning have been completed. M&V equipment has been installed and commissioned.

Next Steps

The project will continue hot water use forecast model development with data from the field demonstrations. Testing the AWHC on HPWH will begin once the API environment is completed. The study will continue to focus on the following tasks:

- Testing MPC performance in simulation, and on HPWH in lab.
- Expand Data Model Framework to include space conditioning system and building models.
- Start building laboratory benchtop test setup for ASCC.
- Prepare retrofit of AWHC and ASCC and monitor control performance for 9-12 months.

The project is scheduled to be completed by end of Q1 2024 but is currently in the process of asking for a one-year no-cost extension from the CEC.

DR21.01 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.

The current ratings for residential/small commercial HVAC systems are based on traditional steady state lab test methods that are not sufficiently representative of field performance. Dynamic testing or load-based testing is necessary to better characterize the performance of the actual advanced controls of these heat pump systems. TTC seeks to build an environmental test chamber capable of advanced dynamic HVAC testing at the facility in Irwindale, CA.

Current TTC HVAC lab test capabilities are limited to steady state methods that disable native HVAC controls. A dynamic test method, such as CSA EXP07, produces metrics/results that include operation of native controls. It is important to find out if HSPF2 and SEER2 or SCOPh and SCOPc 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 projects HIL and HP-Flex (A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop approach, Next Generation Heat Pump Load Flexibility), F-Gas Reduction Incentive Program.

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

Collaboration

The project is being co-funded by the Technology Test Centers, the SCE Emerging Technologies program, and the SCE Codes and Standards program.

Results/Status

National supply chain issues significantly delayed vendor selection and equipment procurement associated with HVAC dynamic test chamber construction at the TTC taking place Q3-Q4 2022. Planning took place to identify alternate pathways to build upon existing equipment and design retrofit chamber controls. Renovation of the facility layout was completed in Q4 2022. Completion of test chamber planning and vendor selection is targeted for Q2 2023.

Next Steps

Dynamic test chamber planning will be finalized Q2 2023. The project targets dynamic test chamber completion by Q4 2023.

DR21.03 Dynamic Rate Pilot

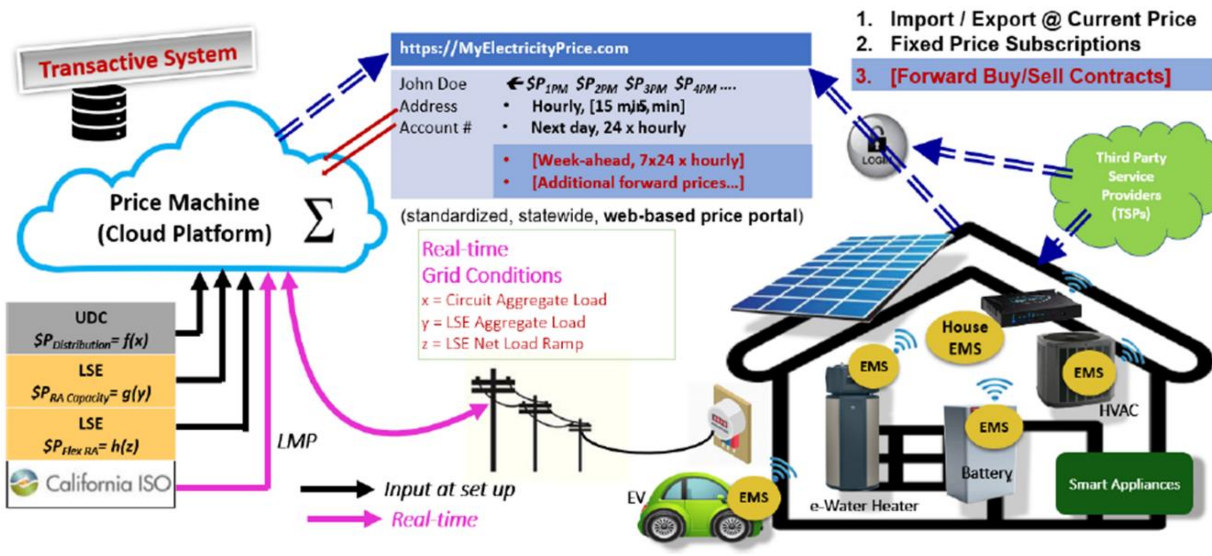
Overview

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

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

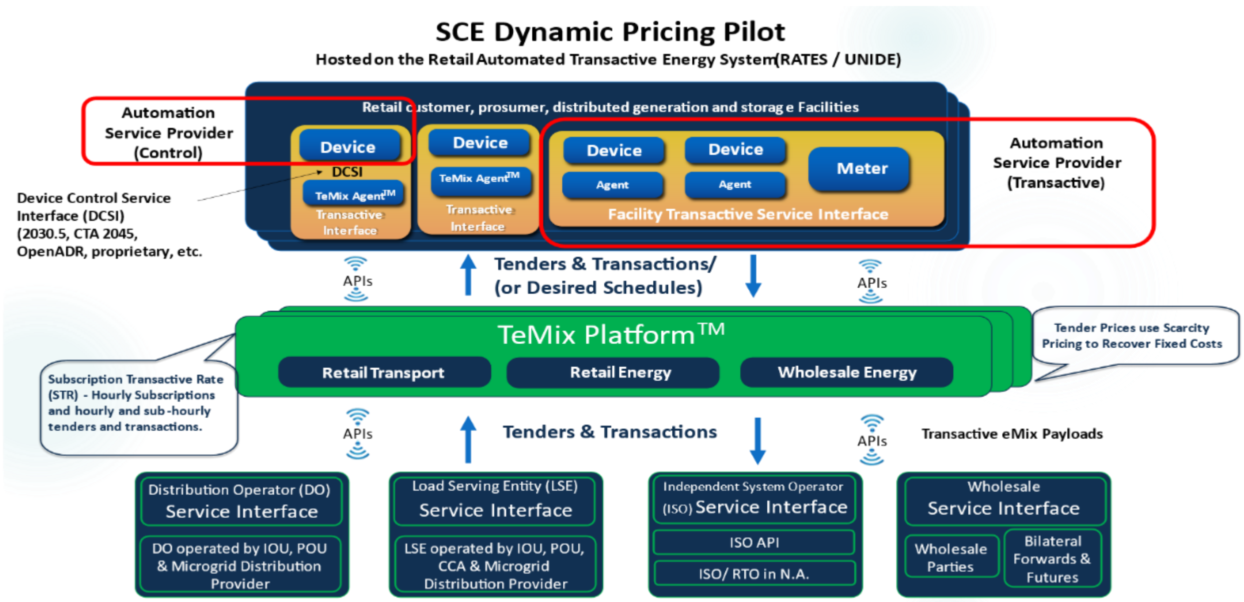
SCE was encouraged to enroll residential, commercial, and industrial customers in this exciting demonstration. SCE will work through reputable Automation Service Providers (ASPs) with existing relationships with these customer types and previously installed automation software or hardware at these customers'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

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



CalFUSE Concept for Dynamic Rate Design

The Pilot will combine real time pricing design and transactional subscription elements from the CalFUSE tariff architecture. So that the CalFUSE hypothesis is 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, automated service providers (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 there are elements of both research goals in this study. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities. The Technology Transfer category advances DR-enabling technologies to the next step in the adoption process by raising awareness, developing capabilities, and informing stakeholders during the early 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 machine provider to use the TeMix platform software service as directed in the CPUC decision. TeMix proposes for the Pilot to provide this software services platform for a period of three years or longer, with the option for extended services as needed. 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.

SCE will also work with other stakeholders such as ASPs, 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 charging and discharging schedules). TeMix provides optimization agents for use by the vendors to assess their applicability for eligibility, security, and compatibility with current APIs (reducing the need for software development).

Electric Power Research Institute (EPRI) is a partner and will provide technology support, having previously worked with both the CEC and TeMix on research projects to facilitate flexibility and responsiveness to dynamic test signals. The customer sectors in prior research included industrial (refrigerated warehouses and water/wastewater facilities) and large commercial office parks and institutional customers (hospitals, state facilities, etc.). SCE will coordinate with EPRI and examine opportunities to engage these and other customer groups to receive TeMix signals like what EPRI has done through OpenADR.

SCE also intends to collaborate with Lawrence Berkeley National Laboratory (LBNL) to leverage LBNL's research with the CalFlexHub. This collaboration will allow SCE to coordinate price messaging protocols and develop an expeditious pathway for alternative messaging transport services that may result in additional customer eligibility for the Pilot (e.g., underserved rural areas and disadvantaged communities lacking Wi-Fi access).

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 also 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.

Additionally, SCE will work to engage other innovative partners who have expressed interest 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

The Pilot has been operational during this reporting period, focusing on the acquisition of the service providers and engagement with internal SCE teams to establish new processes such as dynamic price development, billing meter data transfers, grid forecasts, and data verification which are the first steps of the implementation of the dynamic rate tenders and transactive tariff.

To date, six automated service providers (ASPs) have enrolled to engage with the price machine provider, solicit customer sites for the pilot, and identify end uses and protocols for response to the price signals. Multiple new internal processes have been developed and the price telemetry systems are actively being tested, which require ASP validation of the customer eligibility, including identification and circuit mapping to p-nodes and utility API interfaces.

SCE billing teams are addressing the "Shadow Bill" processes for customer payments with the verification steps to be established once prices have completed their development. The SCE marketing team with the help of customer focus groups completed the creation of customer and vendor-facing informational materials to communicate the Pilot purpose and foster participation.

The ASPs has enrolled eligible customers to support demonstration of the real time pricing design and transactional subscription elements for the CalFUSE price design, which takes elements from both the RATES and UNIDE tariff concepts that were identified in the initial phase of the Pilot. Customers have been successfully engaged by the ASPs from a variety of sectors including residential, industrial, commercial, and agriculture and more ASPs are being engaged as well to grow customer participation.

Next Steps

Project teams continue to work with the SCE teams and the CalFUSE service providers to operationalize the dynamic prices based on the data requirements from the CalFUSE architecture. Collaboration is ongoing between SCE supply chain management, audits, finance, and IT to ensure compliance with customer data and dynamic grid information access, shadow billing processes, transactive subscription rate design, incentive payments, etc.

All pilot teams are continuing to reach out & educate ASPs to assess TeMix API compatibility, the grid location of customers, end-use opportunities, and shadow bill processes. Full dynamic price development and communication to the ASPs and their customers with the end uses in dynamic management is expected in Q2 2023 and more customers are expected to be enrolled.

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

Overview

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

LBNL FLEXLAB Test Site

The proposal submitted by LBNL was titled "A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop approach" and was awarded a contract agreement by the DOE for $1.6M to fund the development of a framework to characterize the performance of building components in providing flexible loads and building services using a hardware in-the-loop approach. 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) in support of LBNL's proposal titled "A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop approach" in response to the DOE's BENEFIT FOA 0002090 solicitation, intending to cost share $300,000. This DOE project will generate high fidelity measurements of building system energy use and their ability and performance to provide grid services and demand flexibility while maintaining acceptable levels of service to building occupants. It will measure demand flexibility for different grid services and system/building types (commercial) and generate data for researchers/policymakers.

Research questions include:

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

The project objectives are:

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

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

Collaboration

The project is supplementary to work funded by the DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019". SCE is working with LBNL as a funding partner and active reviewer of the work in progress.

Results/Status

SCE-LBNL contracting for the co-funding agreement with deliverables for SCE's investment was completed in Q4 2022 and the work at LBNL is ongoing.

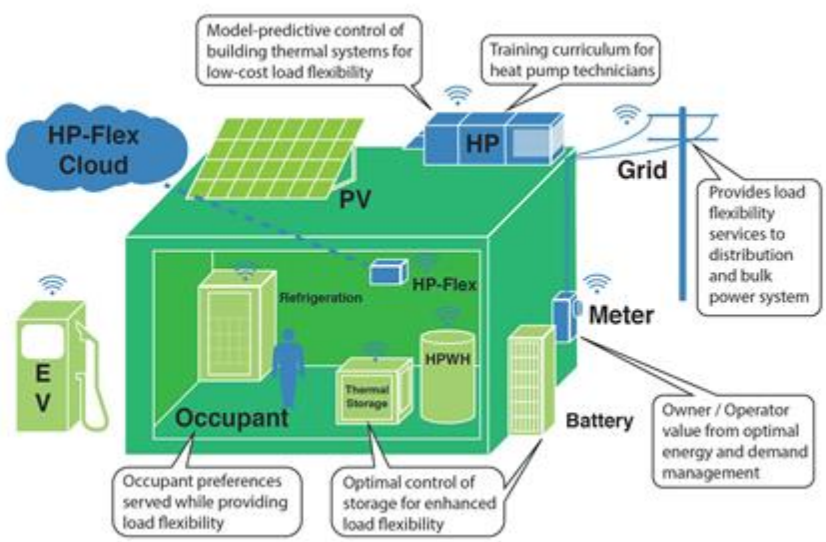
Next Steps

LBNL and SCE have ongoing coordination as the project progresses. This will include presentations/sync-ups, provision of modeling plan test procedures summary, provision of calibration data, and FLEXLAB experiment results and associated reports. Receipt of deliverables is expected throughout Q1-Q2 2023.

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 solution (called HP-Flex) for optimal demand management of high-efficiency heat pumps in small and medium commercial buildings. The goal of the CEC Agreement 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 (HP) installations in small to medium-sized commercial buildings, to increase benefits to both individual building owners and the distribution grid compared to standard HP installations.



HP-Flex: Next Generation Heat Pump Load Flexibility

Southern California Edison (SCE) provided a Letter of Commitment in support of LBNL's proposal for the EPIC GFO 19-301 Group 4 EPIC solicitation, intending to cost share $300,000 ($150k / $150k from EE & DR funds). The project will develop and demonstrate an open-source energy and load management system designed to control advanced heat pumps on small/medium commercial buildings. This system will minimize energy use and bills while allowing buildings to effectively participate in load shed, shift, shimmy and shape 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 (SMC).
- Verify that HP-Flex integrated in SMC buildings can meet the following criteria: 1) Achieve a 20% reduction in site peak energy costs compared to an SMC 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 SMC 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 payback time of 2 years.
- Integrate and control a thermal energy storage system with a SMC heat pump.
- Develop educational curricula to train engineers and technicians on the design, installation, and maintenance of load-flexible HP 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.

Results/Status

SCE-LBNL contracting for the co-funding agreement with deliverables for SCE's investment was completed in Q4 2022 and the work is now ongoing at LBNL.

Next Steps

LBNL and SCE have ongoing coordination on the following activities/deliverables expected to occur throughout Q1-Q2 2023: the development, technical reviews, and testing of Model Predictive Control algorithms; presentations/sync-ups; associated memos and M&V plans; and selection of 3 or more field test sites in SCE service territory.

4. Budget

The following table represents the total expenditures for SCE's 2018-2022 EM&T authorized budget as of December 31, 2022. These values are based on the authorized funding and expenditures as reported in SCE's Monthly Report on Interruptible Load Programs and Demand Response Programs, Table I-2, SCE Demand Response Programs and Activities Expenditures and Funding submitted on January 25, 2023.

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

Southern California Edison's Emerging Markets and Technology Program (D.17-12-003 and D.21-12-015)	
Authorized 2018-2022 Budget	$17,110,000
Budget Spent to date	$16,050,962

NOTE: The "Authorized 2018-2022 Budget" amount in the table above also includes the funding authorized for the DR21.03 Dynamic Rate Pilot approved in D.21-12-015.