Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q1–Q2 2022

Prepared by:
Southern California Edison (U-338-E) September 2022

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 Programming 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 Q1-Q2 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, issued 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.

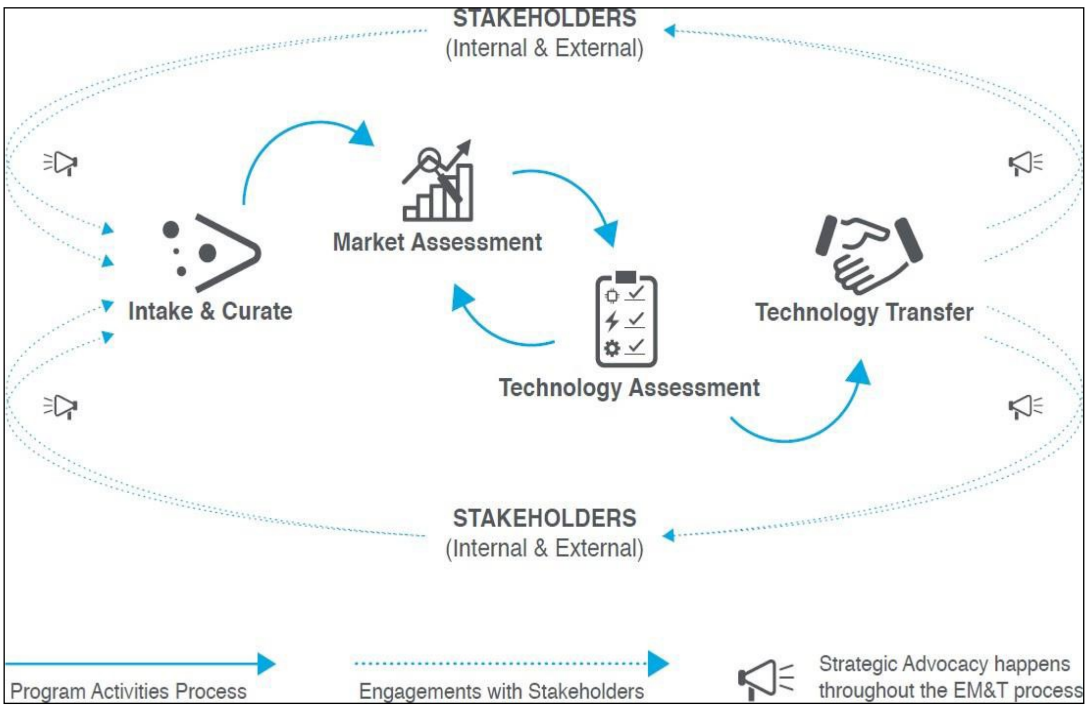
SCE's Engineering Services group in the Customer Programs and Services (CP&S) organization oversees the EM&T program's activities. The program funds these activities through a portfolio investment approach designed to provide maximum value for SCE's customers. The portfolio focuses on advancing DR-enabling technologies for SCE's programs, tariffs, and markets, consistent with the program's funding approval from CPUC D.17-12-003.

The 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:

1. 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.
2. 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.

3. 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.
4. 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.
5. 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 Q1-Q2 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		
DR19.04	Evaluation of Direct Energy Savings and DR Potential from PCM for Cold Storage Applications	Technology Assessments Technology Transfer
DR19.03	Smart Speakers	Technology Assessments Technology Transfer
DR19.02	Low Income Multi-Family Battery Storage, Solar PV, and Data Collection (Pomona)	Technology Assessments Technology Transfer
DR18.06	Willowbrook - Integration to Enable Solar as a Distribution Resource	Technology Assessments Technology Transfer
DR18.05	Residential Energy Storage Study	Technology Assessments Technology Transfer
DR18.04	Heat Pump Water Heater Systems	Technology Assessments Technology Transfer
In-Progress Projects		
DR20.03	DR Technology Enhancements	Technology Assessments Market Assessments
DR19.08	Grid Responsive Heat Pump Water Heater Study	Technology Assessments Technology Transfer
DR19.07	Measuring Builder Installed Electrical Loads	Technology Assessments Market Assessments
DR17.03	Demonstration of Affordable, Comfortable, and Grid Integrated ZNE Communities	Technology Assessments Technology Transfer
Projects Initiated		
DR22.02	LOC-GFO-19-302-4 Next Generation Heat Pump Load Flexibility DR	Technology Assessments Technology Transfer
DR22.01	Hardware in the Loop Flexible Modeling DOE FOA-0002090	Technology Assessments Technology Transfer
DR21.03	Dynamic Rate Pilot	Technology Assessments Technology Transfer
DR21.01	DR-TTC Dynamic HVAC Test Chamber	Technology Assessment Technology Transfer
DR19.11	LOC-GFO-19-301-4 Optimizing Heat Pump Load Flexibility	Technology Assessment Technology Transfer

SCE works collaboratively with the other 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 research findings from the California Energy Commission's EPIC program, and the Department of Energy's Building Technology Office (BTO) research grant opportunities.

In accordance with the CPUC's direction for the reporting of the DR EM&T program, this report covers SCE DR EM&T project activities during the timeframe between January 1, 2022 and June 30, 2022, covering Q1 and Q2 of program year 2022.

2. Projects Completed Q1 – Q2 2022

DR19.04 Evaluation of Direct Energy Savings and DR Potential from PCM for Cold Storage Applications

Overview

This field study determined the effectiveness of phase change materials (PCM) technology to act as a means for refrigeration facilities to "shift" their energy usage and electrical demand. Thermal storage has been examined in various ways to provide various durations of "shed" for traditional demand response programs, but PCM has not typically been used as a tool for enabling other modes of demand response that may provide longer durations.

This technology utilizes the existing walk-in space for storing frozen food and acts as an element of the thermal storage mass by adding more storage "load" via sealed modules on top of the storage racks. The PCM system combines phase change materials designed for cold storage applications of -10º to 0º F (-23º to 18º C) and modified refrigeration system control logic.

PCM Technology Installed in Warehouse

The project test plan assessed both the value of the PCM as a storage medium that provides "shift" and possibly more flexible refrigeration compressor cycling. At least four tests with large walk-in freezers were selected. The project team quantified the value of the PCM technology under various demand response scenarios to evaluate its success at maintaining stored food temperature limits and document any impacts on energy usage.

Test scenarios determined minimum and maximum demand reduction for midday, evening, and nighttime periods for each season, and studied when the maximum and minimum demand reductions occur.

The project confirmed the advantages of constant availability of the PCM on the volume of food storage space. For example, how much time can the refrigeration system be shut off for certain volumes of cold storage? This research offered information about pre-scheduled and dispatched demand response strategies. The project assessed the response that could be expected from various pricing signals to the customer and the distribution system.

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, including raising customer awareness, developing capabilities, and informing stakeholders during the early stages of emerging technology development for potential DR program and product offerings.

Collaboration

The first test was overseen by SCE refrigeration engineers at a refrigerated food warehouse in Rancho Cucamonga, California. The PCM was installed by the authorized installer, and SCE hired a third-party engineering service provider whose engineers installed the monitoring equipment, coordinated the DR scenarios, and reported on the results.

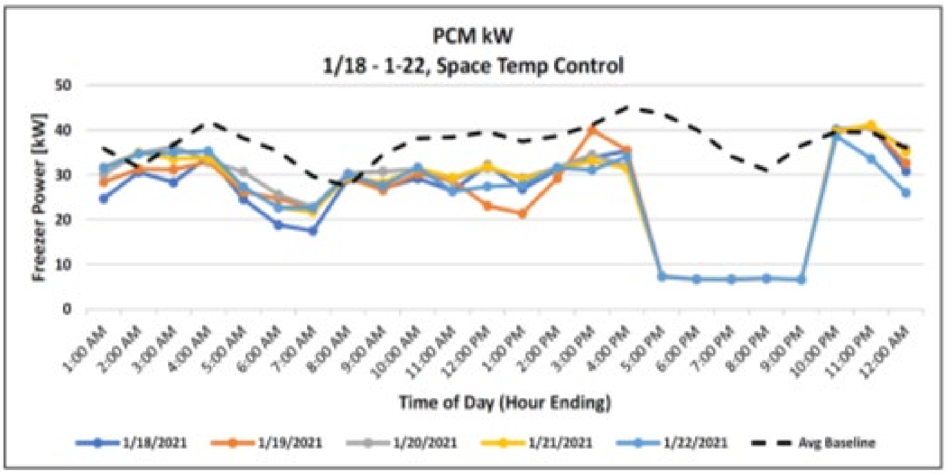
Results/Status

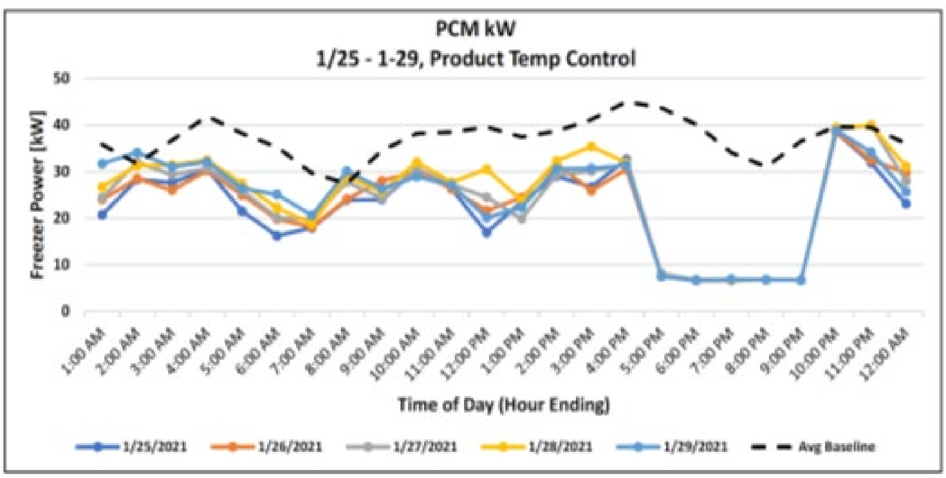
The energy efficiency (EE) and DR evaluations were finalized, and the final report was completed in Q2 2022. Project results confirmed demand reduction benefits associated with installation of PCMs and supplemental controls in a frozen food storage warehouse.

Baseline load shedding capabilities (DR-enabled, no PCM, native controls, space temp control, 4-9 PM-DR-event) yielded a DR-event-measured average refrigeration system demand of 16.4 kW. The PCM measure demonstrated significant incremental load shedding capabilities beyond those of the baseline load shedding capabilities. The PCM increased baseline load-shed DR potential by 9.6 kW (measured DR event demand = 6.8 kW). Supplemental controls (a retrofit controls package, typically bundled with the PCM measure, that interfaces with existing native controls to add additional sensing, monitoring and controls capabilities),with the PCM, further boosted that DR load-shed potential to a total of 15.5 kW (measured DR event demand = 0.9 kW) and were able to extend the reduction hours to 4 PM – 12 AM. Minimal impacts to product temperature were observed under the various DR strategies observed by the test team, as illustrated in the load shed testing graphs.

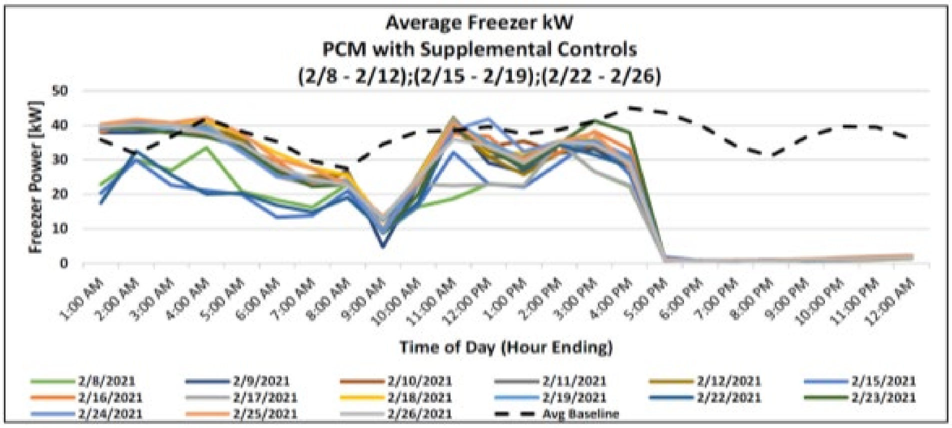
Summary DR Load Shed Testing (Space Temperature Control Strategy)

	Measured Test Demand [kW]	Max Space Temp [°F]	Max Product Temp [°F]	Measured Test Demand Savings [kW]
Baseline	16.4	8.8	5.0	n/a
PCM with Native Controls	6.8	6.3	3.9	9.6
PCM with Supplemental Controls	0.9	8.5	6.5	15.5

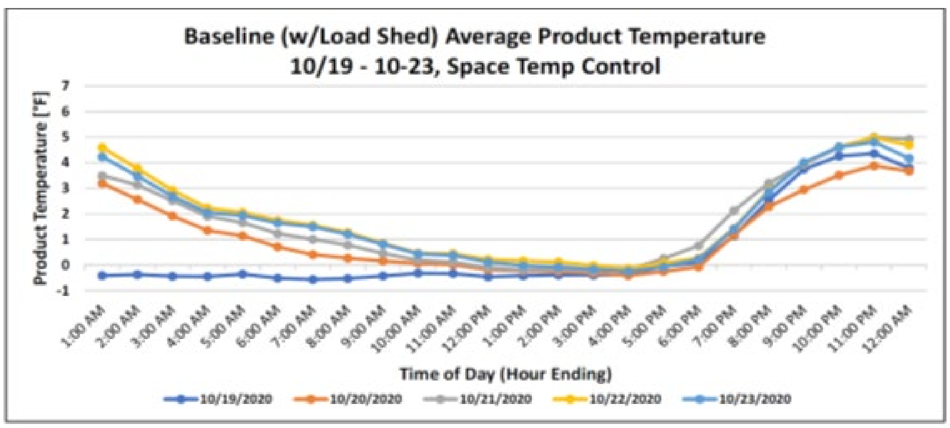




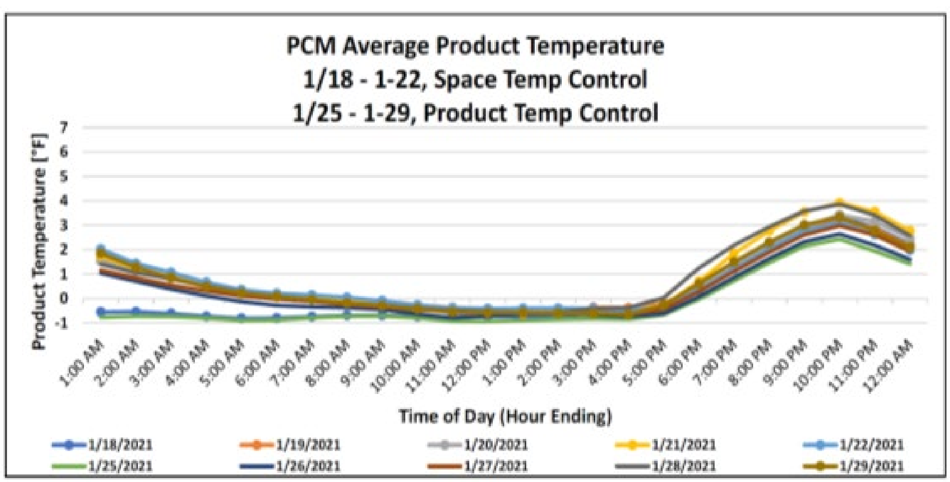
PCM with Native Controls Freezer kW During DR (Space and Product Temperature Control Strategies)



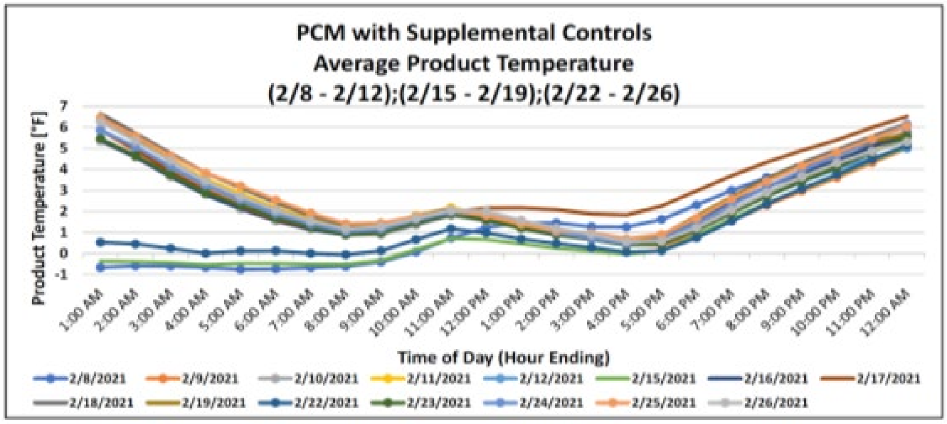
PCM with Supplemental Controls (Weekday Temperature Control Strategy)



Product Temperatures, Baseline Load-Shed Test Event Product Temperature (Space Temperature Control)



Product Temperatures, PCM with Supplemental Controls (Weekday Temperature Control Strategy)



Next Steps

The project results recommended that the PCM be considered for transfer as an opportunity for measures in energy efficiency and demand response programs. Measure transfer activities are continuing.

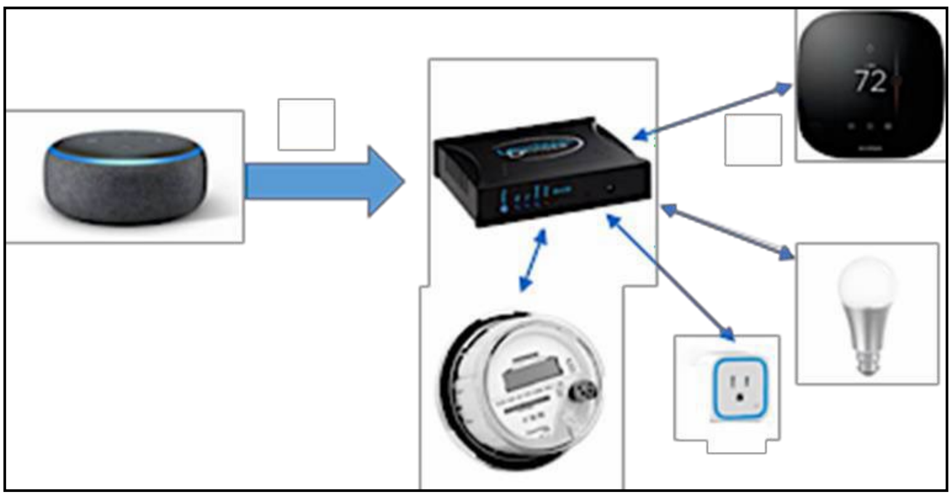
The final report is available online on the Emerging Technologies Coordinating Council (https://www.etcc-ca.com/) and the Demand Response Emerging Technologies (https://www.dret-ca.com/) websites.

DR19.03 Smart Speakers

Overview

Virtual voice assistant devices such as Amazon's Alexa smart speaker series are increasingly popular with residential electricity customers for use in entertainment, shopping, education, and communications. Since 2015, Amazon has sold over 100 million Alexa-enabled devices across the world. Smart speakers have become exceptionally popular. According to public market research reports, as of 2019, an estimated 35 percent of U.S. households were equipped with at least one smart speaker. By 2025, the adoption rate is expected to increase to 75 percent.

With smart speaker technology already integrated into more than 100,000 different smart home products from nearly 10,000 brands in thousands of SCE homes, these devices offer a creative way for SCE to connect with customers (for example, when making a payment or receiving energy-saving tips) and enable smart home devices to effectively manage their energy costs through demand response programs and dynamic tariffs.



In-Home Smart Speaker and Control Equipment

Since customers are changing their digital interactions with utilities — especially within the connected home arena — SCE explored the possibility of a voice-enabled smart home service as a "gateway" for customer interaction. This could allow customers to engage with SCE's demand response rates and programs without having to use a computer, phone, or laptop.

The primary goals of this project were to:

- Better understand how connected smart thermostats and "smart" household end-users can optimize their energy usage via "smart speaker" voice commands subject to SCE's time-of-use (TOU) rates and customer comfort and savings preferences.
- Evaluate how voice interactions related to energy — usage, estimated bill, best times to use appliances — could be improved to identify optimal voice command "skills" and "smart speaker" interactions.
- Develop optimization algorithms and voice interaction vocabulary specific for the new SCE TOU rates and demand response programs.

The secondary objectives of the EM&T Smart Speaker demonstration project were to:

- Better understand how customers can effectively interact with and use the smart speaker and other connected technologies in the home as their preferences for energy management.
- Determine how customer satisfaction is impacted by the customers' experience with smart speakers and connected technologies for managing energy, and if the interaction persists or is just a novelty.
- Estimate the change in customer energy use that can be attributed to the enabling technology of a smart energy management hub with smart speaker and associated Alexa skills as an "integrated energy management package".

Customers in the study received training on how to ask energy-related questions and set their home energy optimization preferences using the smart speaker. A "smart hub" provides algorithms to use various data points, such as the customer TOU rate, energy use, and preferences, to optimize connected devices. Device settings were adjusted to run less during peak times. This project demonstrated the smart speaker's interactive capabilities with household occupants and assessed whether the smart speaker enabled customers to manage their energy use and cost by optimizing all their connected devices.

The project also used a meter-based assessment that is individualized for each home to assess impacts of energy savings, load shifting, and load reduction. The goal was to understand energy usage impacts and to potentially develop a deemed integrated demand side management (IDSM) measure for both residential energy efficiency and demand response programs, using real time meter data to assess incremental changes in usage.

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, including raising customer awareness, developing capabilities, and informing stakeholders during the early stages of emerging technology development for potential DR program and product offerings.

Collaboration

This work leveraged the previous "smart speaker" work funded by the CEC and supported by SCE under the CEC EPIC GFO 15-311 RATES transactive energy project ($3.1M CEC grant). This was a transactive energy pilot that developed certain software and smart speaker skills that are foundational to this current project. This new work was a collaboration among multiple groups within SCE — EM&T, SCE Product Development — other technology stakeholders, and the CEC grant awardees, such as Universal Devices. The technology transfer from this effort leveraged over $3M of original research funding from the CEC project. The M&V study to assess the load impacts or price elasticity effects was conducted by Resource Innovations (formerly known as Nexant) under contract to SCE. No other direct cost-sharing or co-funding with any other parties was utilized.

Results/Status

Project decommissioning, customer notification/communication activities, and project closeout were completed by Q1 2022. Closeout on M&V activities and reporting was completed in Q2 2022. The findings of SCE's Smart Speaker Demonstration Project provided a useful program design template to continue building from. The project was successful in developing a smart speaker "Energy Expert" skill and implementing it in conjunction with a variety of smart devices (dimming/non-dimming light bulbs, smart plugs, and smart thermostats). The skill was designed to respond to the following customer commands:

- "Alexa, open Energy Expert."
- "What devices are being optimized" (what devices are being controlled as part of the project to optimize savings consistent with preferences established by the customer).
- "Start optimizing my [end use device]."
- "Stop optimizing my [end use device]."
- "What is my savings level."

Customers could optimize their devices by setting their savings levels to low, medium, high, or none:

- "Set my savings level to [low, medium or high]."
- "What is the best time to [charge my car]."
- "Enable text notifications."
- "Enable Alexa notifications."
- "What is my electricity usage for [the last 20 days]."

- "How much energy has my [thermostat] used."
- "Which devices were used [yesterday]."

Transcripts of sample interactions are available in the final report.

The following impacts were observed from the integrated energy management package of measures implemented by this project:

- Average summer weekdays
  - Peak period demand reductions from 1.7% to 10.6% (0.03 kW to 0.22 kW)
  - Daily energy reductions from 0.8% to 1.3% (0.26 kWh to 0.38 kWh)
- Average summer weekends
  - Mid-peak period demand reductions from 7.1% to 9.6% (0.16 kW to 0.23 kW)
  - Daily energy reductions from 0.7% to 4.1% (0.24 kWh to 1.45 kWh)

While the impacts of the COVID pandemic stymied program participation, the demonstration project did show promising signs and offers another way to engage SCE customers in a useful dialogue and educate them about their own energy usage. Due to reduced participation, the findings did not result in recommendations for additional measures for energy efficiency or demand response programs.

Key findings and recommendations pertaining to load impacts from the Smart Speaker Demonstration Project include the following:

1. The evaluation was limited by low counts of active participants. Additional recruitment of participants and promotion of skills and features would result in a more statistically significant evaluation.
2. Load impacts are evident for certain subsets of treatment customers and time periods, but the mechanism(s) leading to the effects cannot be definitively attributed without a larger participant population.
3. A large portion of the initial set of participants were inactive by the time of evaluation.
4. Skill log and device level data was sparsely populated. More stringent QC of data collection will allow for a more comprehensive analysis and more refined attribution of observed effects.
5. The specific devices with the most use include smart appliances, refrigerators, thermostats, and interior lighting. Additional education and focus on these end uses could provide the most value to future iterations of this program.

Key process evaluation findings and recommendations stemming from discussions with program and implementation staff include:

1. Existing frameworks of the optimization algorithm and initial Alexa skills benefitted the rollout of the project, but additional skills were developed later, increasing the time between installation and treatment. Since these are now developed and tested, any future iterations of the program will benefit from the foundation.
2. Because the project design required a third-party to install the equipment during the COVID-19 pandemic, this resulted in little participation. The implementer cited customer reluctance to allow people into their homes.
3. Installers could have benefitted from further training and support due to the complexity of connecting multiple devices with the meters and gateways. The implementer received frequent requests for additional support from the installers, particularly when the SCE program manager was not present on-site to oversee the installation.
4. Home equipment was occasionally installed incorrectly and did not communicate with SCE's smart meter. The program implementer reported problems with incorrectly installed thermostats and connectivity with the SCE smart meter. Additional validation that the equipment was accurately installed and is communicating with other equipment may be beneficial. Also, presetting home equipment to the largest extent possible and considering a cloud-based approach instead of hardwires could also prove effective.
5. Customer outreach seemed to be beneficial in improving engagement with the devices, particularly after the launch of the additional smart speaker skill capabilities. Providing regular outreach and education on program updates would likely increase program impacts.
6. Given that the typical customer profile for the demonstration project is engaged with home automation topics and technologies, customers could potentially be instructed on installation of equipment as well, though perhaps with a smaller subset of the components involved in this project.

Next Steps

Project decommissioning, customer notification/communication activities, and project closeout were completed in Q1 2022. Closeout on M&V activities and reporting was completed in Q2 2022. The final report is available online on the Emerging Technologies Coordinating Council (https://www.etcc-ca.com/) and the Demand Response Emerging Technologies (https://www.dret-ca.com/) websites.

DR19.02 Low-Income Multi-Family Battery Storage, Solar PV, and Data Collection

Battery Energy Storage Systems (BESS) and solar PV systems are being integrated into multi-family, owner-managed residential building portfolios at a growing number of sites across California. This project assessed how BESS can provide demand response benefits, along with the potential impact on local distribution transformers, the distribution infrastructure, and customer electric bills. These interactive effects need to be better understood so SCE can provide better customer support for future DER installations, improve the models for grid infrastructure design and planning, and gain experiential data from these customer assets for new models of DR.

Zero Net Energy Multi-Family Low-Income Facility

This project provided research related to the interconnection, commissioning, system performance, customer objectives, and grid impacts of the installed energy storage system and PV array installed at Pomona Mosaic Gardens and provide knowledge transfer for similar energy storage projects. The multi-family housing complex at Pomona Mosaic Gardens was identified by SCE's Emerging Markets and Technology (EM&T) research program as a key venue to test and validate function, operation, and value of battery energy storage in the context of PV solar and customer loads. The project characterizes the changes in the building's load shape and grid impact qualities associated with behind-the-meter (BTM) customer-sited energy storage.

The project provided a better understanding of how the various BESS, PV, smart inverters, and related components work as a system in the context of low-income or other multi-family housing, and how they can act as a DER to provide grid-responsive services, "shift" for dynamic pricing response, or backup energy. The focus was primarily on storage acting as a DR resource.

Battery Energy Storage System in Multi-Family Building

To enable the DR operation of the battery storage system, the project leveraged previous BESS research to gain a comprehensive understanding of the system's performance and its benefits and impacts for the customer and grid operator as a possible new DER resource. The study provided an in-field case study for SCE and its technical stakeholders to support continued adoption of customer energy storage as it impacts tariff compliance, customer and grid economics, and technical grid services that might be achieved through independent and coordinated operation of these potentially flexible assets.

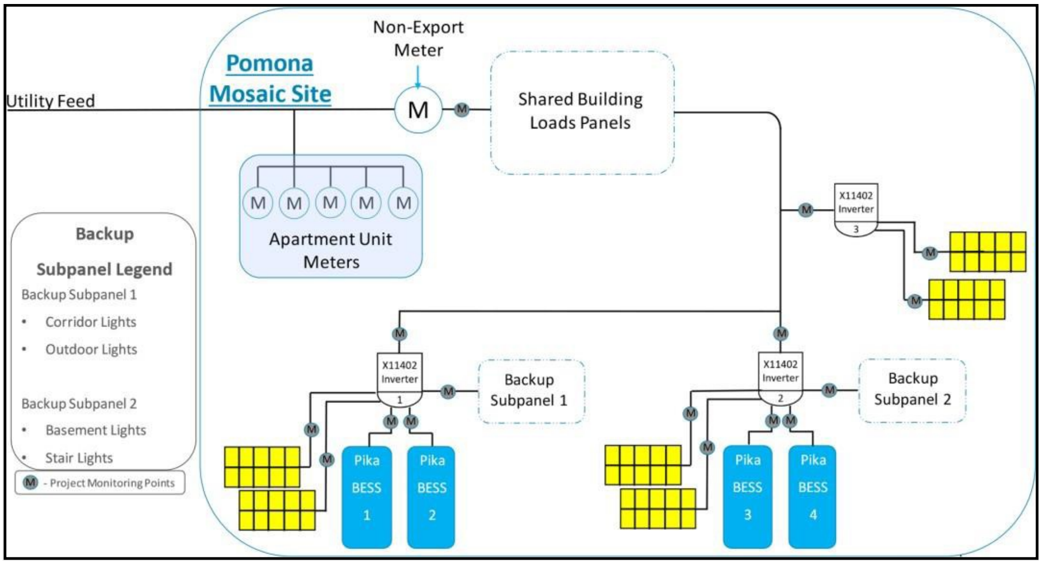
Performance testing of the paired solar and energy storage solution provided SCE with valuable information on the characteristics of the building energy storage system with islanding inverters, as well as its impacts on the customer building performance and the local grid equipment. SCE's research interests in customer-owned storage are emerging and broad, and as customers increase their adoption of solar plus storage systems at the multi-family level.

SCE's objectives were to learn how these systems can:

- Create incremental grid value in locations with demonstrated needs (for example, areas with reliability-related service interruptions, distribution circuits experiencing high loads, etc.)
- Create incremental customer value above the typical use case for PV-paired battery systems. Efforts may help to unlock additional customer value streams (e.g., satisfaction, incremental customer revenue streams from grid deferral, etc.)
- Assess Product Design and Cost Assessment: What are the features of various products and total cost of ownership? How do storage products installed in the field perform in comparison to manufacturer specifications and owner expectations?
- Achieve Technology Readiness: Are products able to be safely and reliably deployed with robust operations? What are actual deployment experiences, as well as standards and requirements that apply for installation, safety, operation, monitoring, and integration?
- Document Real-World Operating Conditions: How do storage products operate and what is the resource availability outside of standard lab conditions in real-world environments, including weather extremes and conditions exceeding manufacturers specifications?

Performance assessment of electric storage at a high-efficiency "zero net" building to better understand the issues posed were accomplished by developing a detailed test plan which characterized the energy storage system itself, as well as grid service- based operations and customer service-based operations. Several dispatch strategies were examined, as well as assessing which secure communications approach and set of protocols were applicable.

The specific assessment of the energy storage system as both backup and as a distributed energy resource (DER) included characterization of round-trip efficiency, battery module degradation, depth of discharge, and power capacity at variable states of charge. Grid service characterization covered non-export constraints, and recommendations for potential modifications to the control and operation of this and similar energy storage systems. Retail energy time-shifting and solar self-consumption services are often considered customer services but can provide as much or more benefit to the utility as well.



Solar/Storage Electrical Overview with Smart Inverters

The secondary objectives of this project were to demonstrate how customer storage can be leveraged and to quantify impacts to both customer and grid stakeholders. The research focused on the following areas:

- Interconnection for non-export systems: Providing lessons learned and best practices that developed during the initial phase of the project
- Characterization of battery modules under operation in accordance with the dynamic pricing schedules and opportunities for demand response impacts
- Grid Control Strategy: Understanding the objective of the parties involved, grid services, customer applications, and how certain control modes are focused on achieving one or the other, or both simultaneously for load balancing
- System Performance: Evaluation of efficacy of energy storage systems and software regarding
    - Control and communication, both local and remote
    - Grid services and tariff compliance, and customer uses and applications
- Economic Analysis: Characterization of customer economics and grid benefits associated with this system, and similar optimized systems, based on specific control strategies and values such as deferred costs and loss of load

This project was executed in several phases. SCE first completed the battery and solar interconnection and then proceeded to design validation to ensure interconnection was completed as intended. Any issues found were reported and repaired. Issue identification and resolutions guide SCE's future work with customer-sited energy storage, and how M&V can be achieved accurately. The research team also advised on appropriate installation techniques, including appropriate metering to achieve project objectives and the appropriate choice of backup loads chosen to ensure appropriate results. This achieved test objectives, while providing the customer facility with resiliency during power outages.

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, including raising awareness, developing capabilities, and informing stakeholders. This occurs during the early stages of emerging technology development for potential DR programs and product offerings.

Collaboration

This work was a collaboration between two SCE groups: The EM&T program and a team of technical experts from SCE's Transmission and Distribution Strategy group, with support from Kliewer and Associates for field work and oversight. The building owner is LINC Housing which has a 37-year history developing multi-family housing for elderly and low-income residents and was an active and supportive participant in the work. The Electric Power Research Institute (EPRI) supported this project through the collection and analysis of monitoring data and the development of a test plan to examine demand response communications, interconnection (non-export) and value characterization of the BESS installed by SCE.

While the research and storage systems were funded by the EM&T program, SCE leveraged its membership in EPRI with learning and best practices from the parallel research by other EPRI utility members as a cost-sharing strategy. Also, as a corporate funding member of EPRI, SCE is co-funding parallel research investments with other utilities and leveraging that research to assist in this market assessment study, but no other direct cost-sharing or co-funding with any other parties was enabled.

Results/Status

The project paired four battery energy storage systems totaling 60 kW with two solar arrays providing a total power capacity of 34 kW. Two 11.4 kW smart inverters connected with the batteries and the PV systems, while a third inverter operated in solar-only mode.

The solar-plus-storage systems allowed operation in a variety of modes to serve both customer and grid needs.

Project Findings

1. Time-of-Use rates encouraging energy storage systems to discharge in the evening, combined with solar-only charging, may leave energy storage systems without adequate capacity for backup during the evening hours.
2. Incorrect placement of current transformers may create significant issues post installation, and can be prevented by standardized best practice material, as described in the project recommendation section, below.
3. Installation of data monitoring prior to project installation provides historical data essential to some analyses. Full utilization of BESS requires planning at building design in ordering to avoid the need for complicated conduit and network connections that may be difficult to impossible.
4. Effectively scaling efforts in multi-family contexts is made difficult by the complication of having a site that is a hybrid of residential and commercial.

Next Steps

Final project is complete, and the final report is available online on the Emerging Technologies Coordinating Council (https://www.etcc-ca.com/) and the Demand Response Emerging Technologies (https://www.dret-ca.com/) websites.

DR18.06 Willowbrook Low-Income Multi-Family DER: Energy Storage with PV

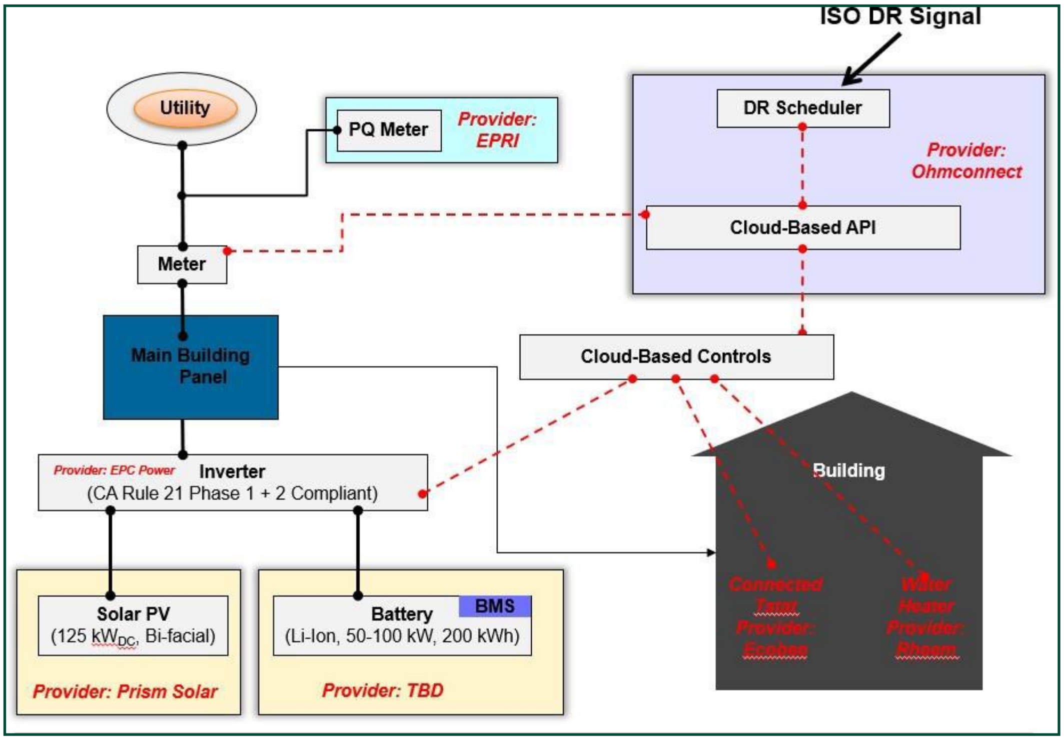
Overview

This in-situ DER demonstration project is an innovative research demonstration study located at a residential community called Mosaic Gardens. This housing was developed by LINC Housing in the Willowbrook neighborhood of Compton, California. The building consists of 61 apartments with 1, 2, and 3 bedrooms, of which half are family housing, and the other half are reserved for formerly homeless and regular users of county services. This project showcased a host of DER technology advances that collectively can contribute substantially to the understanding of how DERs can meet the state's clean energy goals.

Aerial View of the Willowbrook PV Installation

There are many market barriers to the adoption of DER innovation in retrofitting multi-family buildings with solar and storage technologies, and this study, funded by the CEC, will address cost, efficiency tradeoffs, and space constraints. These are all potential barriers to meeting the Zero Net Energy goals in both residential and commercial buildings. Advanced bifacial PV were installed at this site with a target efficiency of about 23 percent. The project studied the use of a DER integration platform that is communications agnostic. The multi-port storage arrangement with smart inverter configurations enabled a "shared savings" model. Relevant M&V efforts included a comparison of pre-versus post-treatment energy utilization, disaggregated by end-use as well as feedback on the customer experience. Customers were trained and provided a smart phone app for energy management.

The project, according to the CEC EPIC grant funding opportunity that was awarded to EPRI, developed and implemented innovative testing techniques to evaluate new configurations for solar and optimization, and how DR dispatch strategies with the storage can be investigated for overgeneration mitigation.



Willowbrook DER Architecture Overview

An overview of the technologies that were demonstrated includes:

- Bifacial solar with target efficiency around 23% that can substantially assist commercial and multi-family buildings with roof area constraints to meet Zero Net Energy goals. Commercial buildings commonly have a lack of roof space for solar, which is necessary for meeting ZNE performance.
- Demonstration platform that can manage both loads and storage to manage diurnal solar production, evening peaks, and increase overall efficiency of solar utilization in multi-family communities. This was achieved using customer-responsive as well as automated demand-side resources (i.e., thermostats, lighting, and HVAC).
- Integration of DC mini-grids that will eliminate conversion losses for solar PV to feed loads and further enhance overall system efficiency, and evaluation of direct DC-powered air conditioners and lighting systems.
- Evaluation of multi-family code readiness for 2020 and future code cycles, analyzing performance at the community and individual level to current code, including meeting criteria for JA5, JA12, and JA13 using DC-integrated solar and storage.

- Integration of solar and storage on the DC side using smart inverters to enable customers with segmentation of storage for meeting various needs, such as peak demand management, utility-controlled distribution grid flexibility, etc.

As part of the CEC EPIC work, EPRI examined the following overarching research objectives:

- What are the combined economics (real and net present value) of a community-level solar plus storage solution?
- What is the feasibility of community scale solar plus storage to attain California's ZNE goals or meet the needs of T-24?
- What are pre- or early commercial technologies that can help overcome economic and field implementation barriers for solar plus storage?
- What are ratepayer and broader societal benefits for community-scale solar plus storage systems given renewable goals?
- What are some alternate business models or arrangements to engage IOUs more effectively in community-scale, customer-sited DERs for both end-customer and grid-support benefits?

The use of DR strategies with storage is a new concept that was investigated in this project, as part of the overall DER design in the building. Specifically, EPRI examined how the bifacial PV and DC microgrid can be optimized with the DER integration platform that will receive CAISO dispatches. The goals of that effort were to design, build, and test the overall community solar, storage, and load control system, which is connected to each DER asset (PV, battery, advanced inverter, smart thermostat, etc.), receive price/control signals from the utility, market, and/or a distribution system operator (DSO), and optimize the aggregated system's dispatch and control for stacked value at the customer and grid level.

The project team also investigated innovative business strategies – such as those informing community solar programs and value-of-solar tariffs – to maximize the value of DER to both end-users and the utility. Another overarching objective of the project was to demonstrate a cost-effective solution for achieving Zero Net Energy (ZNE) within an affordable housing community, and thereby realized California's 2020 goal for new sustainable and scalable ZNE communities.

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 EM&T program is co-funding the DR portion of the overall project that was being designed and operated by EPRI under a contract with the CEC's EPIC program. Other partners included LINC Housing, Kliewer and Associates, and OhmConnect (some of these are partners to the EPRI grant). While the EM&T program is funding the project through a contract with EPRI, SCE also leveraged 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 purpose of this project was to identify scalable community models to maximize the economic benefits of solar PV energy systems for low-income multifamily populations and to evaluate how these technologies could enable grid flexibility, environmental and other benefits that are beneficial to the entire rate base. The project team set out to test technology innovations that addressed this purpose by installing and testing bifacial PV conversion efficiency, the integration of solar and storage with smart inverters and segmentation of storage for various needs, a platform to manage customer loads, strategies to enable greater grid flexibility and reliability at the distribution system level and the use of DC distribution and appliances to eliminate conversion losses.

The results at Willowbrook illustrate benefits that include lowered costs for the property residents as well as greater load flexibility and environmental benefits for the utility and larger rate base. The demonstration also offers technology implementation pathways and lessons learned for more effective project, program, and policy targeting the low-income multifamily sector in California with integrated resource deployments.

The project also revealed the general difficulty for a property owner to meet the due diligence requirements of its property lenders when initiating a solar + storage project on a California tax credit-financed multifamily property. There were a number of emerging technologies in scope that required additional time and resources compared to industry standard technologies to source, integrate, design, permit, interconnect, install and operate. Funding programs and policy must consider interventions for making low income multifamily solar + storage financially feasible.

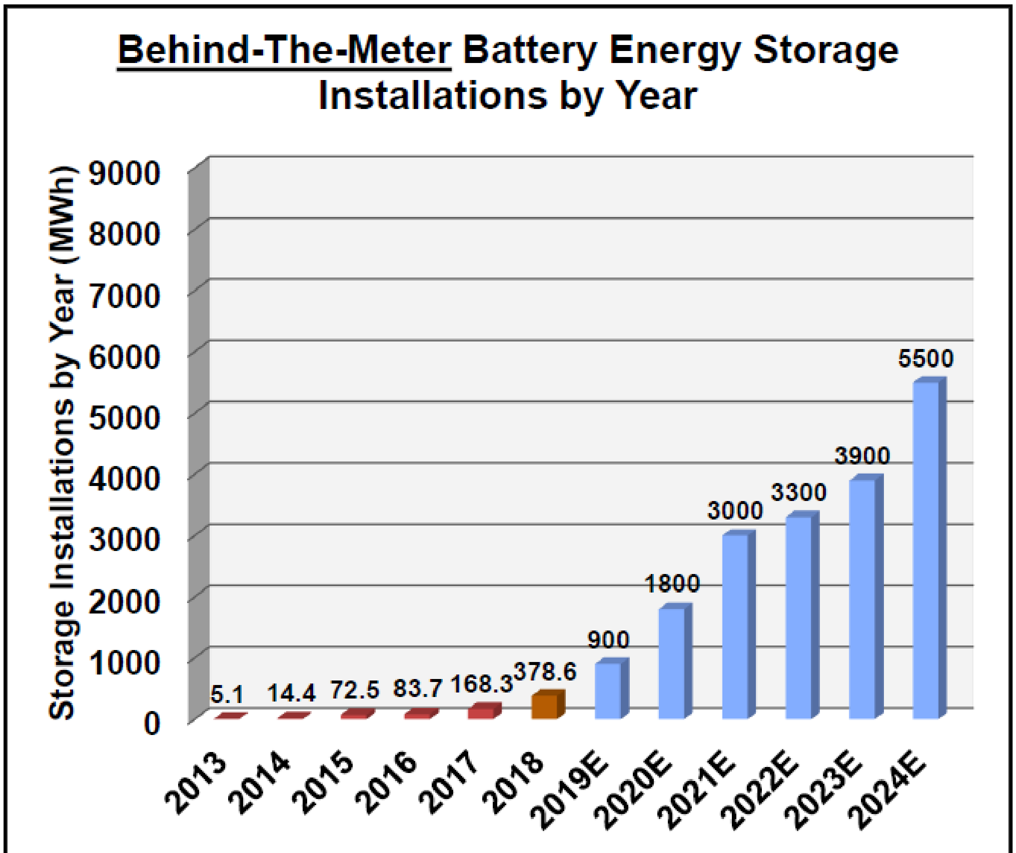
Next Steps

Final project is complete, and the final report is available online on the Emerging Technologies Coordinating Council (https://www.etcc-ca.com/) and the Demand Response Emerging Technologies (https://www.dret-ca.com/) websites.

DR18.05 Residential Energy Storage Study

Overview

Customer-sited battery energy storage products are emerging quickly due to cost and performance improvements in lithium-ion battery technology, and government and utility programs that support grid resilience and improved integration of renewable energy. Storage may be adopted by customers for electric bill savings, backup power, or increased use of local renewable energy. As a result, electric utilities are increasingly faced with the opportunity to interface with customer-sited storage systems, either as interconnected devices or potentially as shared resources with multiple uses.



Source: GTM Energy Storage Monitor data

GTM Energy Storage Monitor Data

Distributed energy storage is regarded as one important solution to support increased distributed solar in California while minimizing operations stress on the distribution grid. SCE and other IOUs, the California Independent System Operator (CAISO), and the CPUC are exploring various approaches to dispatching and compensating behind-the- meter customers. In-home batteries with PV are growing in popularity and installations are accelerating rapidly, especially in California.

The flexibility of the battery to either charge or discharge on short notice has an advantage as it can store energy for later discharge and thus accommodate more variable solar generation. It is important for utilities to understand the systems being interconnected to the grid from functional, safety, and power quality perspectives. The EM&T program developed a project to examine the application of retail tariffs with highly dynamic prices for energy storage and explore the automated dispatch of storage to address customer economics and grid operational issues, with an emphasis on demand response capabilities for shift and shed.

The Residential Energy Storage (RES) project was identified as a venue for testing and validating behind-the-meter energy storage system functions such as load shifting and demand response load reduction. LG Chem batteries with SolarEdge inverters were installed at three homes, and an additional unit was installed in an SCE Smart Home. The project allowed for the extension of concurrent and previously established research that was conducted by a CEC EPIC project (GFO 15.311) to gain a comprehensive understanding of the technical performance of the system as well as the benefits and impacts for both the customer and grid operator.

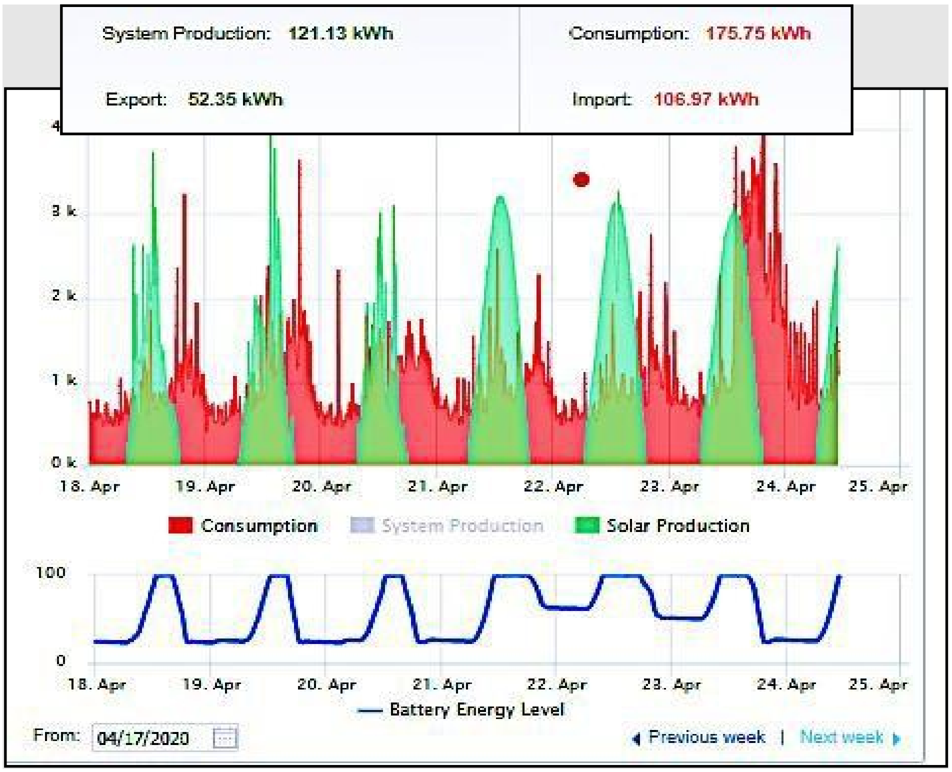
Residential Battery Storage System

Another goal of the project was to better understand how smart inverters can demonstrate the monitoring and automated control of behind-the-meter residential batteries for grid support, demand response, and price elasticity to dynamic tariffs. This project assessed the performance of three residential lithium-ion batteries with SolarEdge smart inverters that were installed and commissioned in the Moorpark area. The research also addressed some important overarching issues around how SCE can include behind-the-meter battery systems to meet the local needs for grid-interactive communities to ensure distribution upgrade affordability, reliability and resilience, and environmental performance. These include the following:

- Dynamic Management: Building end-uses can be designed to help meet grid needs and minimize electricity system costs, while meeting occupants' comfort and maintain lifestyle productivity.
- Resource Co-Optimization: Device design prioritization with buildings to provide greater value and resilience to both utility customers and the grid.
- Integrated Value: Energy efficiency, demand response, and other services provided by facility resources.

The research outcomes from this project prepared SCE and its technical stakeholders for the adoption of customer energy storage as it impacts tariff compliance, customer and grid economics, and technical grid services that might be achieved through independent and coordinated operation of these potentially flexible assets. The research team developed a test plan that examined the following:

- Charge and Discharge Setpoints: The ability to accurately schedule commands for the battery system to charge and discharge are paramount for end users, utilities, and permitting jurisdictions to rely on the further installation of energy storage systems in this and other behind-the-meter contexts for the future.
- Retail Energy Time Shift: Battery energy storage systems can be used to reduce electric bills by using stored energy during times when the retail rate for energy is highest. Given that the utility prices the tariff based on marginal costs for providing power to a facility, this use case and application has potential benefits to both the customer and distribution system. The test plan, however, examined how to maximize customer benefits in accordance with the TOU-D PRIME rate from SCE.



Residential Battery Storage System Charge/Discharge Profile Alignment with SCE Tariff TOU-D-Prime

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

SCE leveraged three residential participants from a previous CEC EPIC grant project, who allowed the battery energy storage system (BESS) to be installed by a third-party systems integrator. The BESS included a SolarEdge smart inverter system, and the LG Chem RESU battery panel installed by Promise Energy. Kliewer & Associates facilitated the system commissioning and city/county inspections of each home and is currently developing a training module for the grid-interactive SolarEdge API that will enable SCE engineering staff to schedule the systems for grid-responsive flexibility testing. The project is wholly funded by the EM&T program and no co-funding or cost-sharing with other utilities, private industry, or other third-party groups was requested or received for this project.

Results/Status

The project successfully demonstrated that monitoring and automated control could be used on four Behind-the-Meter residential Battery Energy Storage Systems (BESS) for grid support and price responsiveness. It also intended to identify problems with installations, Commissioning, and technology integration. Although all three residential installations involved significant complications as described in the final report, the project demonstrated BESS feasibility. The installation at SCE's Irwindale SEE exhibit offers the public as well as building professionals an opportunity to view a functioning BESS up close, and access to the API control without disturbing customers.

Many technology and installation lessons were learned for the future development of BESS as an emerging technology. In addition, the following project recommendations were defined to support future program design and BESS system functionality to support grid resilience:

1. Explore the Dynamic OpenADR Signal
    a. Implement the TOU-D-Prime tariff in the OpenADR server, b) Configure multiple residential sites on the TOU-D-Prime tariff using pricing to drive BESS.
    b. Run four different test cases and compare them on a weekly basis during summer by 1) Existing maximize-self-utilization BESS modes, 2) Simple charge/discharge (such as via SolarEdge portal) based on TOU rates, 3) Optimization based on smart meter data, state of charge, occupancy, price, and device state (load shift/shed), and 4) Simulation of grid distress (PSPS events) and BESS response to utility-generated event notices.
2. Investigate Granular Pricing Schemes
    a. Apply pricing schemes (at as small as five-minute intervals) to investigate response timing and validate the flexibility to respond dynamically to various pricing scenarios.
3. Investigate the Impact of Power Factor Correction via BESS
    a. This requires 50 – 100 customers on the same distribution circuit and demonstrates the ability to improve the power factor of the grid by mobilizing BESS aggregation.

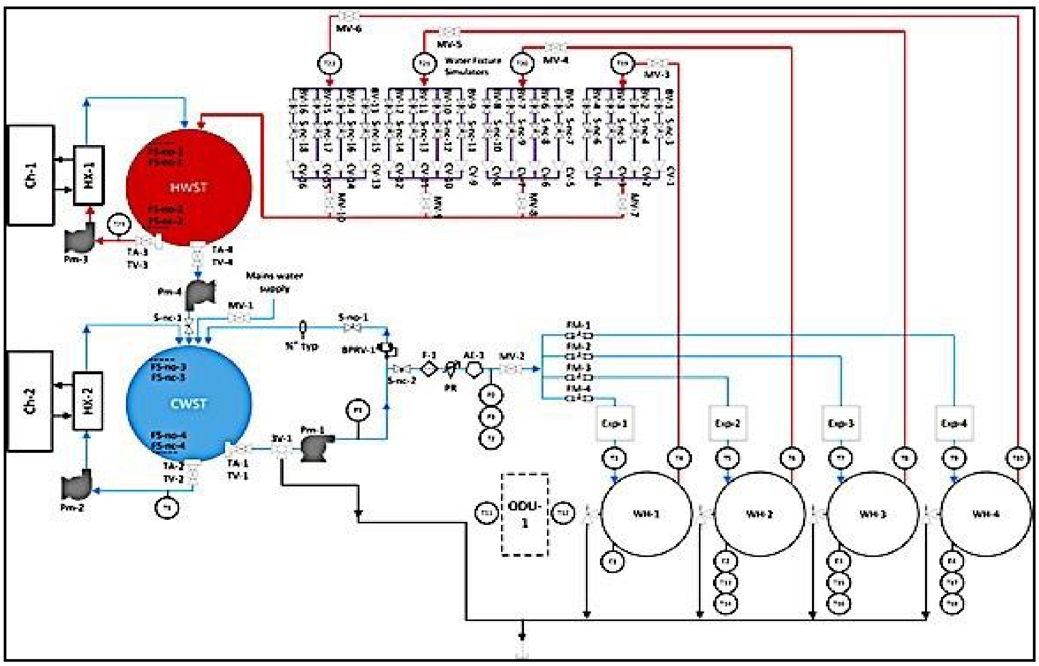
Next Steps

Final project is completed, and the final report is available online on the Emerging Technologies Coordinating Council (https://www.etcc-ca.com/) and the Demand Response Emerging Technologies (https://www.dret-ca.com/) websites.

DR18.04 Heat Pump Water Heater Systems

Overview

The project was developed to facilitate a test environment to assess how electric Heat Pump Water Heater (HPWH) systems can securely communicate and provide time-based operational flexibility under various laboratory conditions. To support that research, SCE designed and constructed a Flexible DR Secure Communications Demonstration Lab for Water Heating Systems at the SCE Energy Education Center (EEC) in Irwindale, California. The project created a lab demonstration for HPWH Open AutoDR (OADR) testing using various transport media to study communication capabilities and integration with the OpenADR 2.0a and 2.0b VEN architecture and CTA-2045 physical layer.



HPWH EEC Lab Design Schematic

The HPWHs in the SCE Lab were modified to a grid-responsive device by either adding a two-way communication device or accessing the existing communications module within the system. The communication device can signal the HPWH to increase the thermostat temperature control during low-cost price periods and will lower the water heater thermostat control during high-price periods throughout the day to reduce energy costs. During higher-priced periods, customers will use water that is already hot. The HPWH's electricity usage is reduced during these peak periods, which, when deployed at scale, leads to a decrease in the amount of energy drawn from the grid.

The key research items that were examined in this project were:

- Load shape and energy demand case studies for HPWHs, based on a wide range of water usage and temperature set point profiles.
- Demand response value propositions for developing flexible load shifting strategies and their effect on water supply, water temperature, and energy usage and demand.
- Test realistic hot water draw events for demonstration purposes and study 24-hour profiles for performance evaluation.

Additionally, the lab provides a future test bed to serve as both a showcase for emerging DR enabling technology for HPWHs, and a highly capable working laboratory for long-term performance studies.

HPWH Test Lab at the SCE Energy Education Center Irwindale, CA

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 demonstration lab was installed in SCE's Irwindale Energy Education Center (EEC) and co-funded by the EM&T program and other sources of funding for the EEC. It will serve as both a fully functioning working lab and an opportunity to engage customers, vendors, and others to assess and review HPWH technologies. SCE also leveraged its membership in

EPRI with learnings and best practices from the parallel research by other EPRI utility members as a cost-sharing strategy.

This project coordinated its research findings with SCE's research partner EPRI and also informed the grid-responsive HPWH investigations underway in the San Joaquin Valley (SJV) Electric Pilot and the Demand Response Pilot for Disadvantaged Communities (DR DAC). Future collaboration with the CEC's EPIC program with participation in their research and possible coordination with the OpenADR Alliance in the development of the CTA-2045 certification testing protocol is planned for 2023.

Results/Status

The Heat Pump Water Heater Lab's data acquisition and control systems were commissioned in terms of electrical and hydraulic functionality. Staff training has commenced across testing guidelines, and Open ADR equipment system panels are being prepared for lab integration and initiate preliminary testing of acquired HPWH products. This will support communication testing of HPWH control strategies and Open ADR grid-responsive initiatives. Essentially the construction at the lab has been substantially completed as of the end of Q2 2022. However, due to COVID-19 access restrictions in late 2021 and through Q2 2022, progress in setting up test projects has been delayed and the lab will not be available for further work until late 2022.

Next Steps

The team intends to finalize Open ADR equipment and cellular/Wi-Fi connections to commence testing of existing HPWH in test bays when access to the lab resumes, which is expected in late 2022. The Lab will continue to plan and prepare for functionally testing support for the deployment of HPWHs in other related SCE projects as needed. The Lab, when opened, is intended to serve as a platform for continued assessment and demonstrations of HPWHs through 2022 and beyond (depending on available funding), at which time the research phase of the project will be initiated.

As this project was designed to support the design and construction of a testing laboratory for HPWHs, the project is now complete, and a final report was not planned. Future research and testing will be specific to the needs of projects initiated, and this development is expected in late 2022.

3. Projects Continued Q1 – Q2 2022

DR20.03 Demand Response Technology Enhancements

Overview

Demand response (DR) programs are important resources for keeping the electricity grid reliable and efficient by deferring increased generation capacity, reducing 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 technologies that are eligible for program incentives, thereby enabling customers to manage their energy costs and time of energy use. One of the key enablers for customer benefits is automated technologies that can facilitate both customer response to DR and do so in both an automated method and in coordination with customer preferences and operating schedules.

The objective of this project is 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 will be identified and assessed.

Further, identification of innovative emerging technologies, software, and market solutions for new models of DR program needs will be identified.

The overall research priorities are as follows:

- Identify applicable tariffs and their characteristics
- Determine what methods can be used to show these tariffs can be communicated to different customers using different communication technologies
- Establish the impacts of the emerging trends (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 California public 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 the California Energy Commission's Title 24 new construction building codes.

The 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. However, 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.

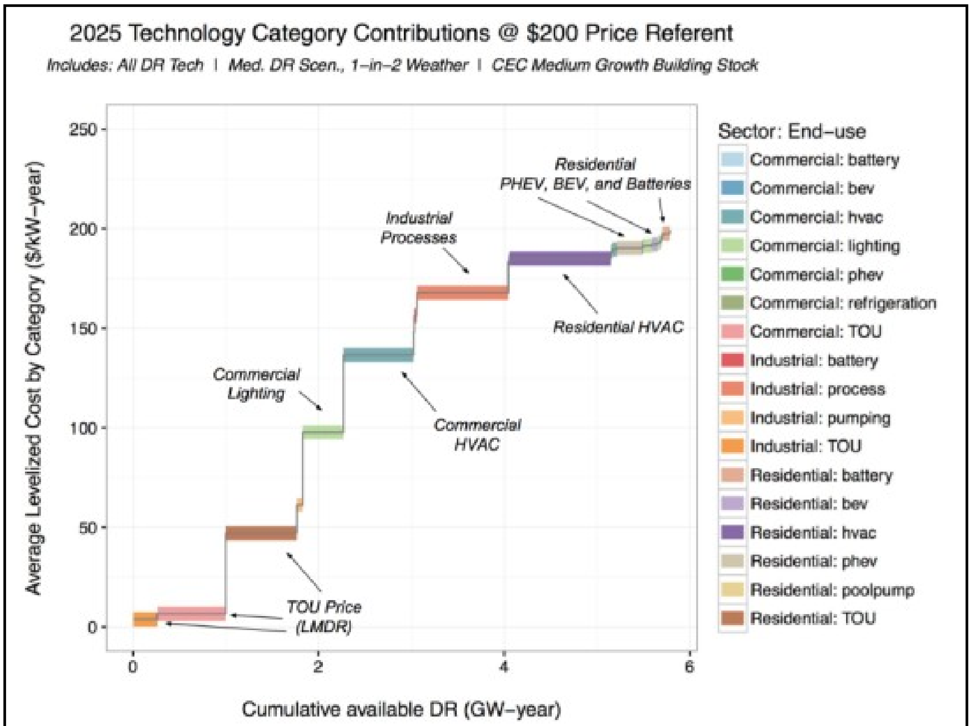


Figure 4: The 2025 technology category contributions below the $200/kW-year price referent. The average levelized costs for each technology category (y-axis) and their contributions to cumulative DR (GW-yr) are shown for the medium DR scenario, 1:2 weather year for all DR technologies.

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. A "DR transformed" 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 will contribute to the understanding of strategies, software, systems, and advanced innovative enabling technologies and identify 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 project 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 would then work with the SCE team to organize these ideas into a set of recommendations. These recommendations would be based on the technical needs assessment and multi-year opportunity matrix that would 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 Open ADR 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 will characterize 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 Open ADR 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 will identify 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 Open ADR 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 Open ADR 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 will be 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 will describe which technologies can be used for core system operation for different applications. In some cases, there may be 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 the 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 the DR automation systems with other energy efficiency investments, they will be explored as well.

This task will also include a review of Open ADR 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 Open ADR 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 will prepare 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 will be identifying new innovative technologies and software in the market. SCE’s EM&T program will be utilizing LBNL to assist with market solutions for advancement of SCE’s DR initiatives to its customers. The EM&T program will work 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. Also, as a corporate funding member of EPRI, SCE is co-funding parallel research investments with other utilities and leveraging that research to assist in this market assessment study, but no other direct cost-sharing or co-funding with any other parties was requested or received.

Results/Status

The project was delayed due to contractor personnel issues (COVID-19 related) and a change of the lead researcher at EPRI to replace the former research lead. While the data gathering phase of the project was completed in early 2021, the subsequent data analysis and development of the final report was delayed by several months. EPRI needed more time to complete the final technical factor reviews and to socialize the outcomes from the protocol comparisons with the SCE review team and external stakeholders. This took additional time through the end of 2021 and delayed the delivery and review of the draft report for the project.

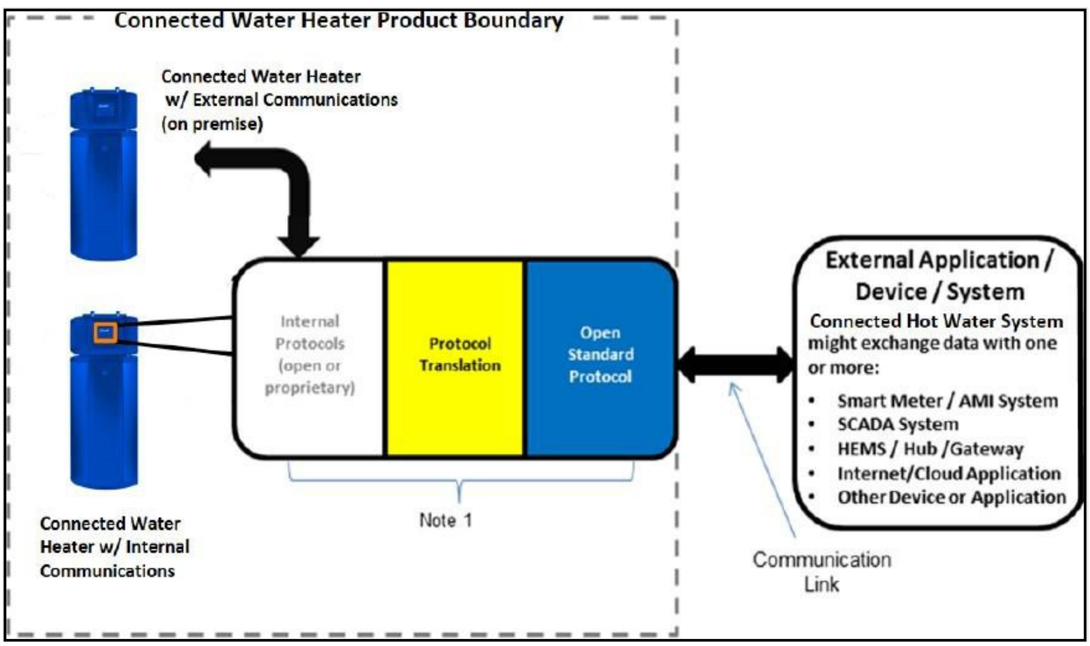
Next Steps

This research study is now back on track to present a multi-year opportunity matrix that will focus on both pre-commercial and near-term cost-effective solutions to enhance future SCE DR activities in support of the DR products group as recommendations from the EM&T program. Each of the five project tasks are sequential and build upon the research in the previous task. Interim reports have been delivered as the work has progressed, and additional technical review meetings have been held with relevant stakeholders via webinar. The draft report is completed as of Q1 2022 and is expected to be finalized in Q3 2022, and this deliverable will also include a final webinar presentation to the SCE teams.

DR19.08 Grid Responsive Heat Pump Water Heater Study

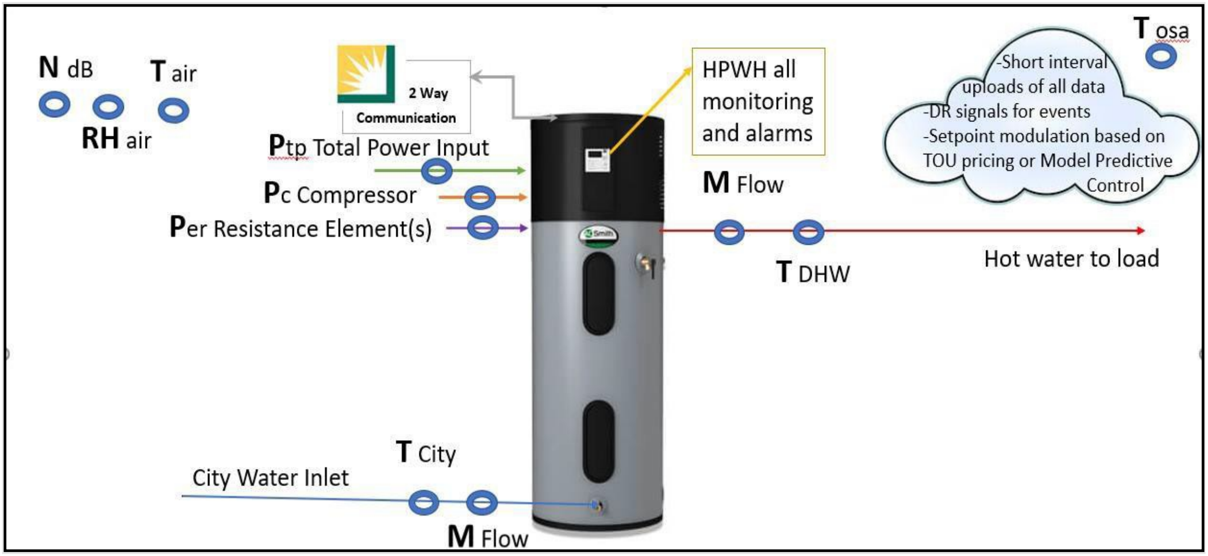
Overview

SCE's Energy Efficiency Emerging Technologies Program (ETP) and Emerging Markets and Technology (EM&T) Program have been conducting technology assessment studies of heat pump water heaters (HPWHs), and this study is a continuation of those efforts. The research team will be examining innovative emerging data management technologies that will be applied and implemented for the deployment of the HPWH controls and communication equipment, and for the test instrumentation and data collection. 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 heating 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 be instrumented 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 had a garage or indoor area for the HPWH and no recirculation systems. The 12 homes were selected from a pool of customers that were part of a larger electrification pilot of 150 homes. This pilot sought to electrify homes and reduce emissions within the SJV. The prime General Contractor (GC) and Community Energy Navigator (CEN) of the larger pilot project were responsible for the overall customer selection and the selection and installation of the grid-controlled HPWH and a proposed communication package to be used by SCE for the grid responsive signals.

The SCE Grid Responsive HPWH study sought to minimize the impact of its M&V installation activities on the participating customers by coordinating with the larger pilot's HPWH installers, and by using a modular M&V setup and using a HPWH installation "mock-up". The SCE Grid Responsive HPWH study plans to minimize the risk of any failures of the HPWH technology that might occur at the customer's home; therefore, the HPWH controls and the grid-responsive communications technology will be functionally tested in a laboratory environment simultaneously along with HPWH deployment in the pilot homes.

The project is 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 and will be assisted by SCE's technology consultants. The SCE Income Qualified Program group oversees the SJV DAC Pilot and will work collaboratively with the research team to select the customers for the study. Community leaders from the San Joaquin Valley and the communities of California City, Ducor, and West Goshen will also be involved. The project is jointly funded by the EE, DR, and the Energy Savings Assistance (ESA) and California Alternate Rates for Energy (CARE) programs.

Results/Status

The project team continues its collaboration with the SJV DAC Pilot team and customer site recruitment activities. Monitoring equipment and instrumentation were installed at all twelve sites. Installations were delayed because of enrollment challenges due to COVID-19. Data is being collected and being checked for quality.

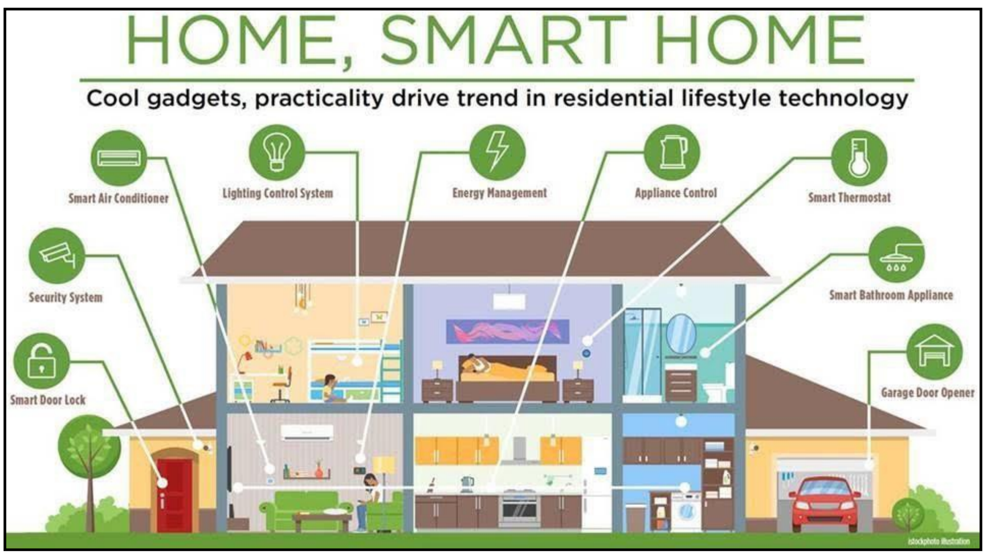
Next Steps

The project team will continue to collect data, test communication for the grid-responsive signals, and begin data analyses on performance and grid benefits. Troubleshooting will be undertaken if there are any anomalies in the data. The overall impact to the project schedule and timing of the data collection due to the COVID-19 restrictions and supply chain issues has continued to slow the HPWH research activities. The project is estimated to continue into 2023 with the overall schedule yet to be determined.

DR19.07 Measuring Builder Installed Electrical Loads

Overview

The home builder or contractor mostly selects and installs the permanent (or "hard-wired") electrical appliances and components in new homes. The minimum energy efficiencies for the common appliances — air conditioners, heat pumps, heat pump water heaters, pool pumps, refrigerators, etc. — are determined by standards, so the home builder's impact on 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 group includes EV chargers, communications infrastructure, batteries, and security equipment. These devices communicate through various protocols to both in-home hubs and via the cloud. The figure below illustrates just a few of the devices appearing in new homes.

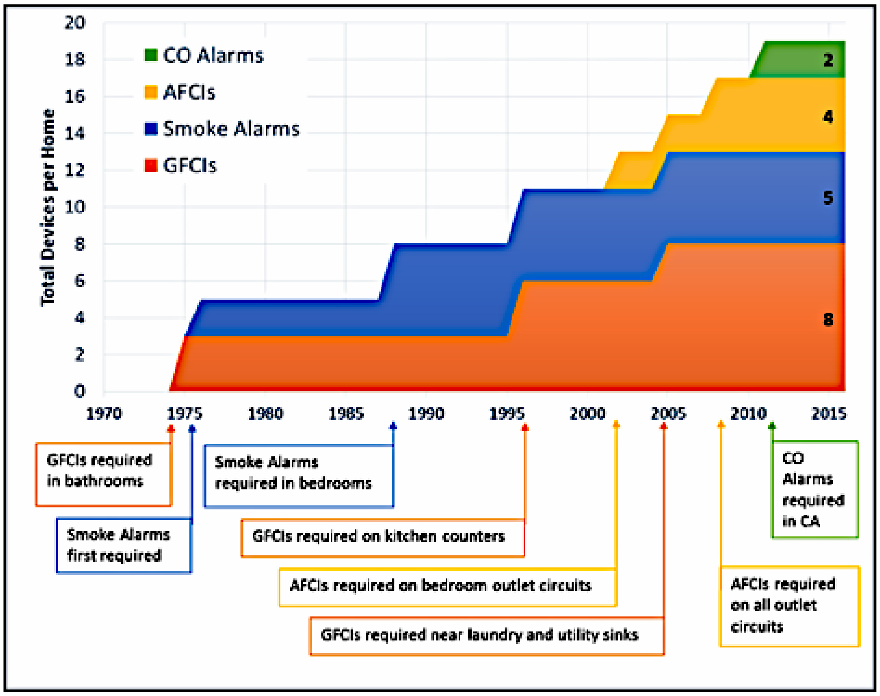


Smart Home Technologies Illustration

These devices provide diverse services, but they are connected in the sense that the builder is responsible for their selection, installation, and commissioning.

Builders and clients are uniquely challenged to make rational trade-offs because little consistent information is available on costs, features of energy and power consumption, and demand. In contrast, SCE has close connections with developers and builders, which gives SCE a unique opportunity to influence decisions regarding equipment selection in future smart homes, either through information or incentives. The first step, however, is to understand the "builder-installed" loads.

Anecdotal data from an ongoing CEC EPIC project suggests that builder-installed electrical loads are contributing as much as 1,300 kWh/year in total power usage in new homes, even before occupants have moved in. No information is currently available to assess how this impacts load shape. This first phase of research is needed because this aspect of residential energy use has not yet been carefully studied. Also, 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

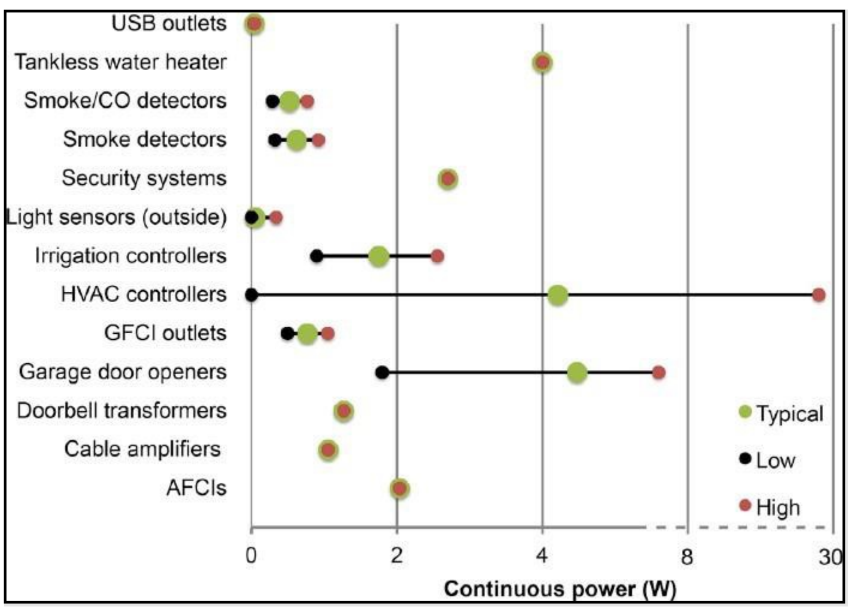
The research objectives of this project are to:

- 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 new 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. Short-term, whole-house power measurements were to be taken from new homes during a relatively short time period between the completion of construction and move-in of the homeowner. However, pandemic restrictions made the original on-site approach unfeasible. Instead, literature surveys, smart home builder websites, technology publications, manufacturer websites, ENERGY STAR-qualified product lists, interviews, and builder-supplied documents were leveraged. Some limited field and laboratory measurements were done to support the information gathered.

The research team identified builder-installed electrical devices found in new, smart homes in California and other relevant locations. The team collected bills of materials and information about actual construction practices in new homes. Focus was on non-standard appliances and devices (that is, not air conditioners, refrigerators, lights, etc.) and all-electric homes. The team prepared a list of devices and their technical characteristics.

The information was assembled in the form of typical homes, with estimates of types of builder-installed devices, their power, load shape, and energy use. Thus, a main product was 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 was on early-adopter configurations; however, some homes with a more modest collection of smart devices was also be included.



Summary of Typical Builder Installed Loads

In the second phase of the project, the research team created a model of prototype home data that can hold builder-installed device data and perform simple calculations. This included home information such as floor area, and device characteristics such as load shape and demand shifting opportunities. The team created six "smart home" prototypes with builder-installed devices based on the bill of materials. The team then calculated 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 investigated the gross load impact of builder-installed devices, calculated the whole- house load shape for each prototype, and evaluated 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 Market 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 SCE's Energy Efficiency Emerging Technologies Program 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 will be conducted with researchers at the advanced buildings section of the LBNL facility, EPRI, and coordination with builders through SCE Business Customer Division.

The project was co-funded by the SCE Energy Efficiency Emerging Technologies program.

Results/Status

Due to project delays, the project report was expected to be finalized in Q3 2022, and the resulting closeout meeting is also scheduled for Q3 2022. This project was successful in providing a better understanding of the builder-installed electrical loads (BIELs).

From the preliminary data collected to date, the overall direct load impacts of BIELs amounted to roughly 13.1 kilowatt-hours (kWh)/day in a small home to 19.7 kWh/day in a large, upscale house (peak demands of 2.5 kW and 4.5 kW, respectively). In the upscale house, 36 percent of the total BIELs energy consumption was due to standby and constant-on devices. Unlike previous studies, these figures account for the impacts of direct load and indirect savings while the home is occupied. BIELs increase with floor area but not with respect to climate. The findings are summarized in Table ES-1. This study found the standby consumption of newer smart homes to be up to three times greater than the 1,050 kWh/year result from previous studies. With a few exceptions (such as stoves), BIEL electricity use is flat and therefore does not substantially increase demand at any particular time. When combined, these constant consumptions can add up to 360 W. Thus, builder-installed loads (excluding those covered by Title 24 and federal energy efficiency standards) in new smart homes will not contribute significantly to future peak demand challenges.

Summary of Energy Consumptions for the Six Typical Homes

	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

BIELs 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 watts. For comparison, 360 watts corresponds to roughly 45 percent 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. SCE laboratory studies demonstrated a wide variation in the standby power consumption of these devices. Furthermore, devices such as Wi-Fi routers appear to operate very inefficiently in the range at which they operate, so even greater energy savings potential exists if their ability to power-scale can be improved.

Next Steps

Due to project delays, the project report is expected to be finalized in Q3 2022, and the resulting closeout meeting is scheduled for Q3 2022. Next steps are to complete the closeout meeting and identify any future research opportunities.

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

Overview

The research goal of this project is to demonstrate the design and installation of advanced DER measures for all-electric Zero Net Energy (ZNE) homes within the multi-family housing sector. A secondary objective is to study how ZNE homes in this segment perform with solar and thermal storage. The mission will be to develop the strategies for effective integration with the electric grid. This project will include 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 are being assessed.

Architectural Rendering of ZNE MF housing

Project outcomes aim to offer:

- Guidance for the development of the next iteration of buildings that will meet the planned 2020 and beyond requirements of the Title 24 California Energy Code for OpenADR communications and flexible appliances
- 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 developer of this project (Meritage) will be installing an integrated all-electric measure package consisting of numerous energy technologies for customer interest and to enhance desirability and comfort, as follows:

- 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 will additionally provide 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 Transfer 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 is a collaboration between SCE, EPRI, and Meritage Homes, which is a builder and seller of multi-family housing. SCE is providing technical assistance with design, construction management, and demand response innovation review.

The project is being co-funded by the SCE Emerging Market & Technologies program and is supplementary to work funded by the CEC Electric Program Investment Charge.

Results/Status

This community of 44 multifamily homes distributed over eight buildings is fully occupied except for a couple of model homes. These homes are monitored with circuit level monitoring in 28 out of the 44 homes. Sixteen of the 28 homeowners have signed data agreements that allows for continuous data collection from these homes.

The data from these homes are analyzed to understand the DR potential in the community in terms of kW of load that is attributable to HVAC and water heating which are the major controllable end-uses. The community has 66 kW potential for DR in Summer and 29 kW for DR in Winter per DR event assuming full community participation.

Significant challenges exist in automating the implementation of DR as the HVAC and heat pump water heaters use proprietary Application Programming Interfaces (API) that do not allow for easy integration with 3rd party DR management systems. The inability to integrate proprietary APIs led to the investigation of behavioral DR. Persistent challenges in the form of limited community interest in participating in DR events through 3rd party DR Auction Market (DRAM) Aggregators calls for approaches to improve customer engagement in this community for the DR potential to be realized.

Next Steps

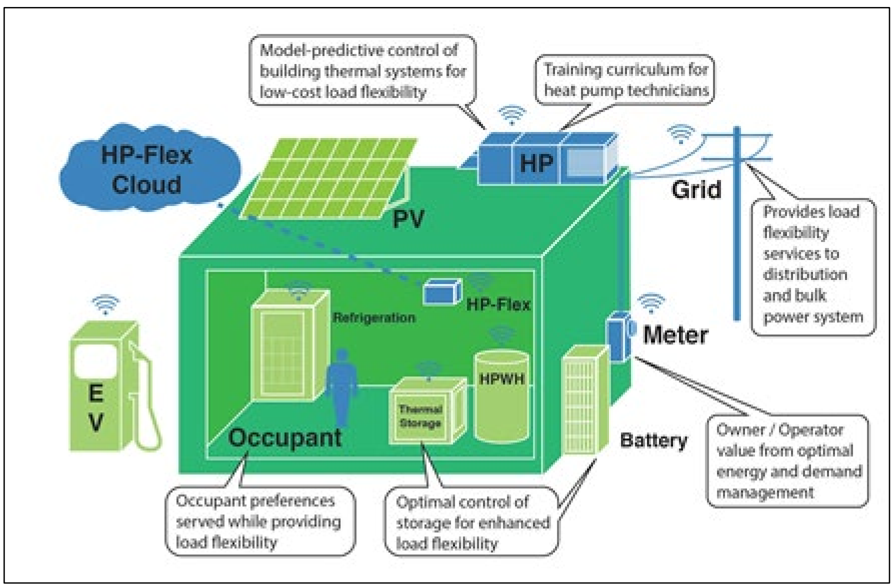
Comprehensive analysis of data from this community is currently underway including insights on challenges and opportunities for programmatic DR implementation in all-electric ZNE communities. A final report including this analysis and insights is expected by Q4 2022.

3. Projects Initiated Q1-Q2 2022

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 provide cost share. 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 to:

- 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:
    - Achieve a 20 percent reduction in site peak energy costs compared to a SMC heat pump with scheduled thermostatic control.
    - Provide 50 percent load shed during summer or winter peak-load events.
    - Provide 20 kWh of daily load shift capacity for a typical SMC building during the shoulder seasons.
    - Provide "shimmy" services equivalent to 10% continuous response of average baseline load.
    - Enable 25 percent of the baseline load to respond to dynamic prices to shape daily load profile in summer and winter.
    - 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 co-funded under the EM&T Market Assessments and Technology Transfer 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 Energy Efficiency Emerging Technologies program and is supplementary to work funded by the CEC Electric Program Investment Charge.

Results/Status

SCE-LBNL contracting is underway.

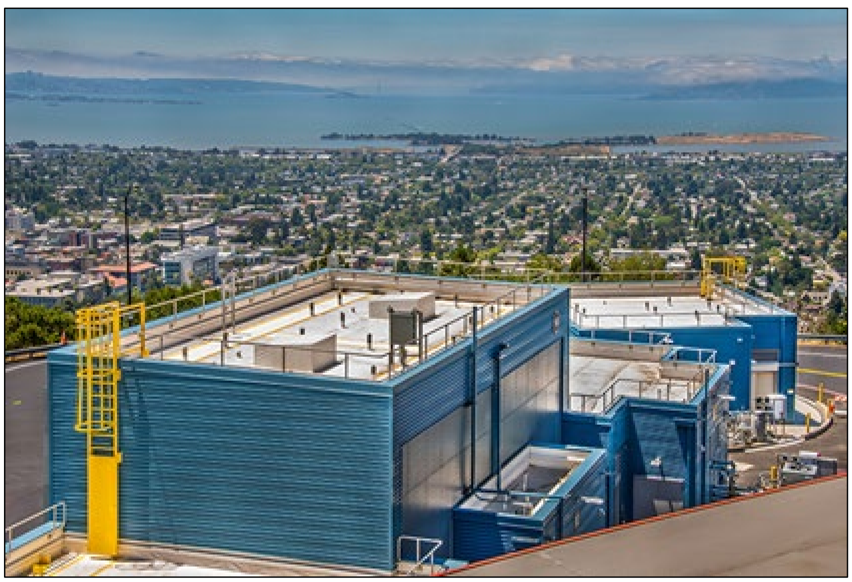
Next Steps

Finalize SCE-LBNL contracting by Q4 2022.

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 for 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". LBNL 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 provide cost share. 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:

- 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 five different scenarios (e.g., a mix of weather, occupancy, building characteristics)
- Development of test procedures to measure building flexibility
- 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), and
- 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 Transfer 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".

Results/Status

SCE-LBNL contracting is underway.

Next Steps

Finalize SCE-LBNL contracting by Q4 2022.

DR21.03 Dynamic Rate Pilot

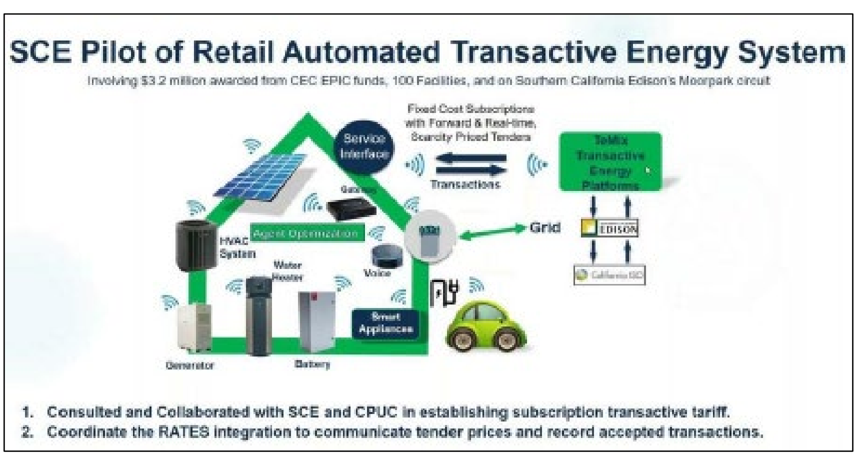
Overview

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 CPUC led UNIDE framework using TeMix Incorporated's Software-as-a-Service (SaaS) solution can meet the needs of the proclamation. This demonstration will "conduct comprehensive studies that fully assess the costs and benefits of real-time rates, including required infrastructure, manufacturer interest, and customer impacts."

The CPUC directed SCE to conduct comprehensive studies across multiple use-cases and assess how the UNIDE framework using a two-part tariff, known as the Subscription Transactive Tariff (STT), will impact infrastructure, electrical device manufacturers' interests, and customers while meeting the goal of Gov. Newsom's order. The decision instructs SCE to administer this demonstration under SCE's Demand Response Emerging Technologies (DRET) program.

SCE is 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 will utilize the STT and a given ASPs' solution to connect customers' devices and systems to TeMix's SaaS.

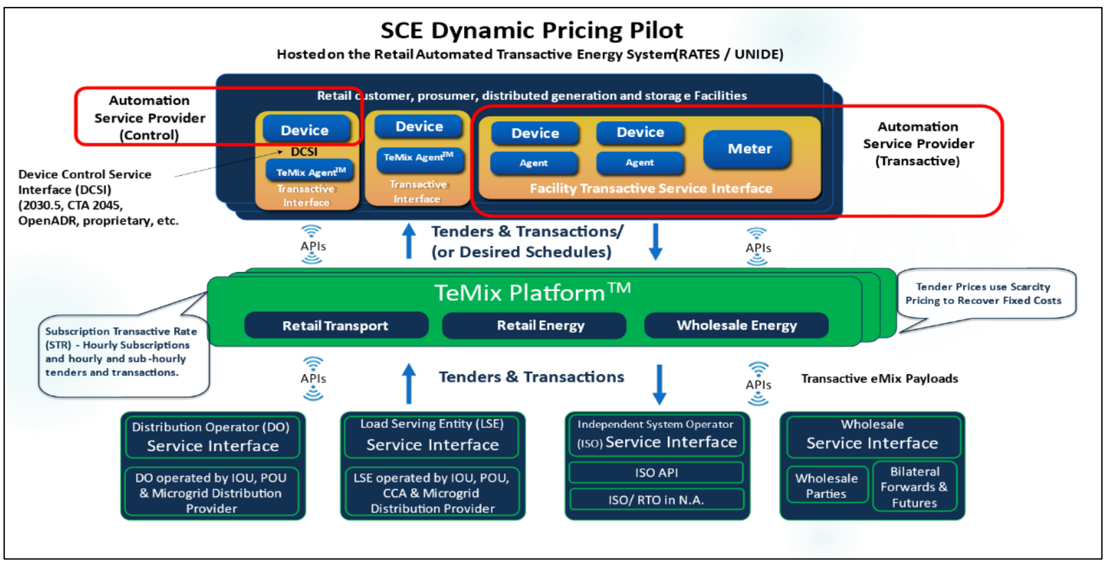
Upon entering the demonstration, each customer will be provided a tailored subscription for their monthly electricity use; based on an analysis of their historical usage. Then, throughout the pilot, via their ASP, the customer will receive highly-dynamic energy rates; that reflect grid conditions and be able to make either buy or sell transaction leveraging this subscription to better meet their operational needs against the needs of the local grid conditions.



The Dynamic Rate Pilot will:

- Combine real time pricing design and transactional subscription elements from both the RATES and UNIDE tariff concepts. This is a prudent approach to enhancing and scaling up a system-wide demand flexibility approach to improve system reliability and enhance customer benefits.
- 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.

So that these hypotheses are 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 2016 CEC EPIC RATES pilot into flexible customer demand side opportunities that can accelerate solutions for system reliability for the summers of 2022 and 2023.



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

Collaboration

To implement the Pilot, SCE executed a service contract with TeMix to use the TeMix platform software service. 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 UNIDE tender transactions for settlement purposes.

SCE will also work with other stakeholders such as current 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 the UNIDE tenders from TeMix and optimize (on behalf of the customer) end use flexibility strategies (such as EV and storage charging and discharging schedules). TeMix will provide 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) has several CEC EPIC research projects that use a similar secure communications platform (Open ADR) and have 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 the TeMix signals like what EPRI has done through Open ADR.

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. Additionally, SCE will work to engage other innovative partners who have expressed interest in collaborating in 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 is now operational as of May 1, 2022. SCE is meeting continuously with Temix staff to accelerate process developments. pricing and design past first step of the rates transactive tariff in pricing and design in coordination with Energy Division. SCE is also enrolling automated service providers (ASP) to engage with TeMix and provide customer sites for the pilot and developing pilot partners contracts. Multiple processes are being developed for the first time, that include customer identification and circuit mapping to p-nodes and utility API interfaces, and API coordination and in collaboration with PG&E. SCE Internal Teams are addressing Shadow Bill processes and verification steps are in development. The Pilot members are developing customer and vendor facing brochure to support the Pilot purpose and participation.

The ASPs are currently enrolling customers to support the demonstration of the real time pricing design and transactional subscription elements from both the RATES and UNIDE tariff concepts.

Next Steps

The project team is continuing to work with TeMix and Energy Division to operationalize the data requirements for the RATES platform and the UNIDE dynamic processes. Working with 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 and educate Automated Service Providers to assess TeMix compatibility, location of customers, and end-use opportunities and shadow bill processes.

DR21.01 DR-TTC Dynamic HVAC Test Chamber

Overview

SCE Technology Test Center (TTC)

The SCE’s Technology Test Centers (TTC) evaluate 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, California.

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.

The project objectives are to:

- 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 are 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, and Next Generation Heat Pump Load Flexibility), and F-Gas Reduction Incentive Program.

The project was funded under the EM&T Market Assessments and Technology Transfer 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 Technology Test Centers, the SCE Energy Efficiency Emerging Technologies program, and the SCE Codes and Standards program.

Results/Status

National supply chain issues have significantly delayed vendor selection and equipment procurement associated with HVAC dynamic test chamber construction. Planning is underway to identify alternate pathways, to build upon existing equipment, and design retrofit chamber controls. Facility layout renovation is currently in progress and targeted for Q4 2022 completion.

Next Steps

Will complete the TTC facility layout renovation in Q4 2022 and finalize the dynamic test chamber planning by Q1 2023.

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

Overview

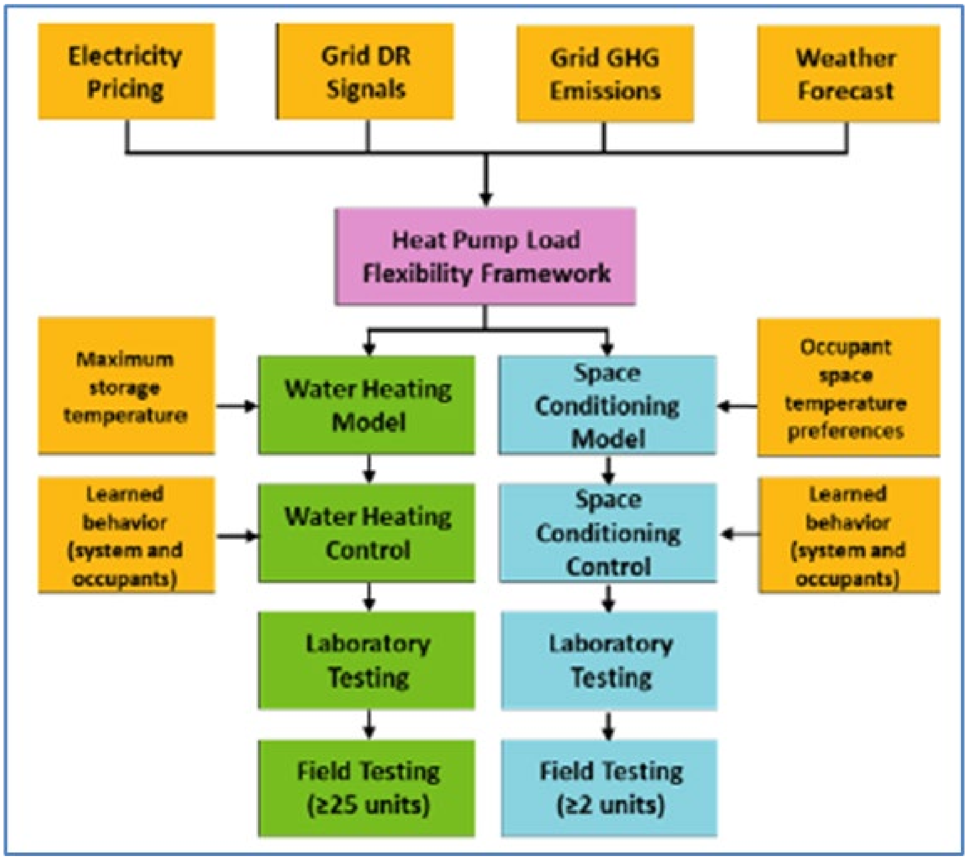
This CEC EPIC project will develop, test, and demonstrate an open-source framework for heat pump load flexibility controls that will be employed for both Advanced Water Heating Controls (AWHC) and Advanced Space Conditioning Controls (ASCC), with the goal of providing a common platform that can be leveraged 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 impactful and efficient, as most of the data needed for a heat pump load flexibility controller (e.g., electricity pricing, grid DR signals, grid emissions, weather) are not specific to the heat pump end-use type (see the figure below titled, Overview of Project). 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 will modulate 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 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 as to when the heat pump operates. 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 to 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.

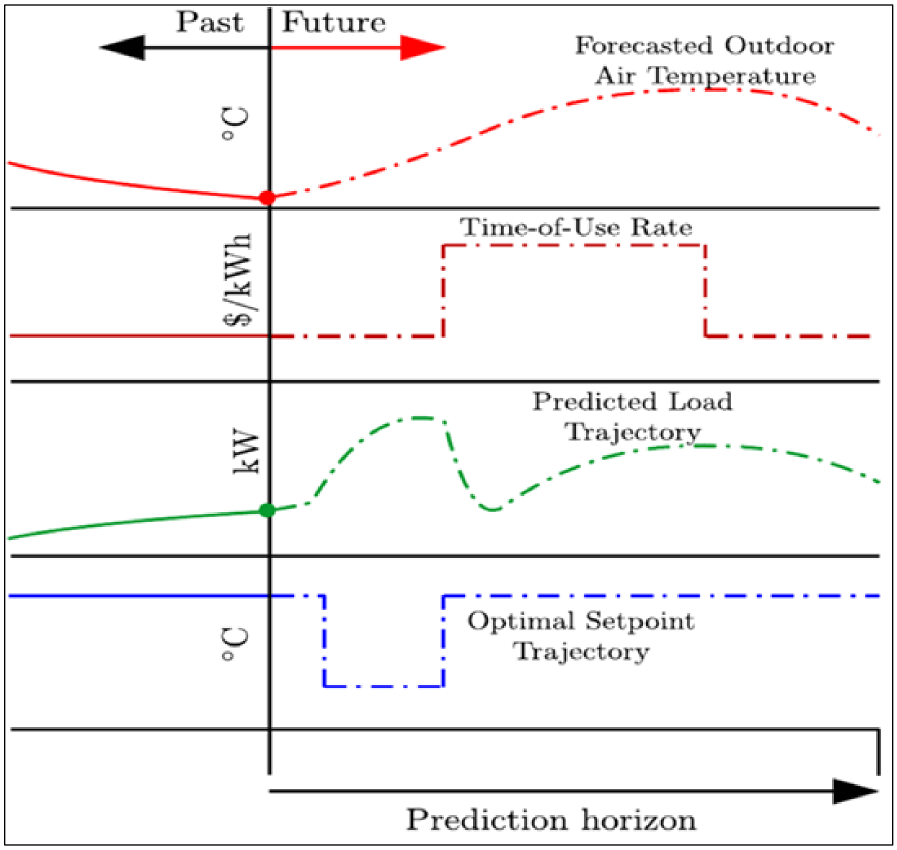


Overview of Project

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.
- 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. See the figure below titled Model Predictive Control.



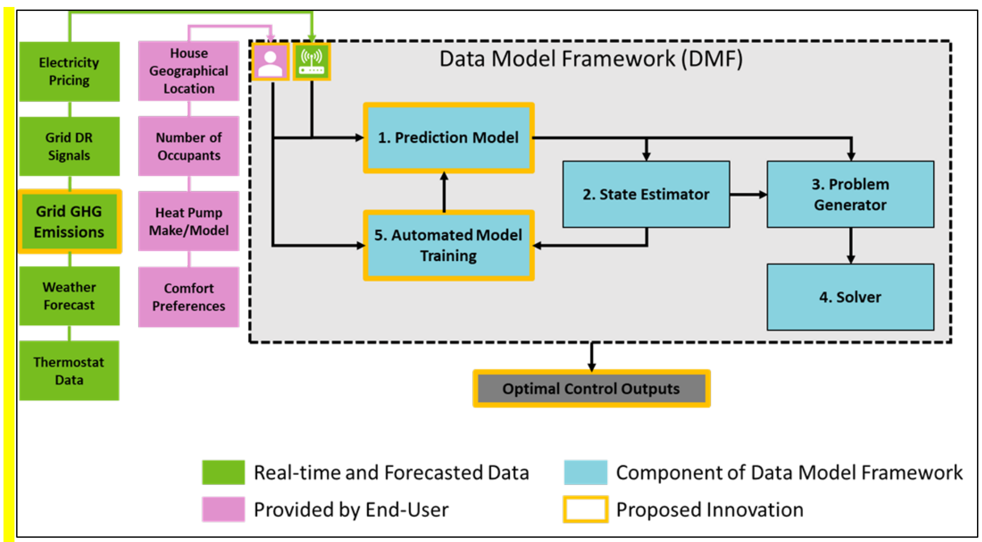
Model Predictive Control

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) see figure below, 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.



Data Model Framework

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 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 WCEC under a contract with the CEC's EPIC program. Other partners include TRC Engineers, Inc, WattTime, Mutual Housing, Quetzal Gardens, ecobee, Rheem, Carrier, and SCE (some of these are partners to the WCEC grant). 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 funding member of WCEC, SCE has insights to ongoing research and leveraging that research to assist in this study.

Results/Status

Several project tasks are in progress concurrently. Literature review for the market characterization has identified key points and data gaps for the expert interviews. Initial development of AWHC is progress. Simulation testing on MPC approach is ongoing. Initial testing to validate laboratory HWPW setup has been completed. Analyses of metadata of several households of residential space conditioning use patterns looked into annual trends, summer/winter use, as well as Pre-Covid and Covid 19.

For the field demonstration portion of the project, 26 households have been recruited. Baseline surveys for water heating and space conditioning have been completed. M&V equipment has been installed and commissioned.

Next Steps

Continue hot water use forecast model development with data from field demonstration. Begin collecting HPWH performance data over range of air and water temperatures. Begin testing MPC on HPWH using EcoNet API. Continue testing MPC performance in simulation and on HPWH. Add MIDAS integration to DMF to get time-of-use tariff information. Expand Data Model Framework to include space conditioning system and building models. Start building laboratory benchtop test setup for ASCC. Prepare for retrofit of AWHC and ASCC and monitor control performance for 9-12 months. The project is scheduled to be completed by Q1 2024.

4. Budget

The following table represents the total expenditures for SCE's 2018-2022 EM&T authorized budget as of June 30, 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 July 21, 2022.

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)	
Approved 2018-2022 Budget	$17,110,000
Budget Spent to date	$13,989,422
2018-2022 Budget Remaining	$3,120,578

NOTE: The "Approved 2018-2022 Budget" also includes the funding authorization for the DR21.03 Dynamic Rate Pilot, which was authorized in D.21.12.015.