Demand Response Emerging Markets and Technology Program

Semi-Annual Report: Q3 – Q4 2020

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

March 2021

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Abbreviations and Acronyms

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

EPA	Environmental Protection Agency
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
ESA	Energy Savings Assistance
ET	Emerging Technologies
ETCC	Emerging Technologies Coordinating Council
EVSE	Electric Vehicle Supply Equipment
EVTC	Electric Vehicle Test Center
EWH	Electric Water Heater
FDD	Fault Detection and Diagnostics
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
GIWH	Grid Integrated Water Heater
GWP	Global Warming Potential
HAN	Home Area Network
HEMS	Home Energy Management System
HFC	Hydrofluorocarbons
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IALD	International Association of Lighting Designers
IAQ	Indoor Air Quality
IDSM	Integrated Demand-Side Management
IESNA	Illuminating Engineering Society of North America
IoT	Internet of Things
IOU	Investor-Owned Utility
kW	Kilowatt
kWh	kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LIMF	Low-Income Multi-Family
M&V	Measurement and Verification
MF	Multi-Family
MSO	Meter Services Organization
MW	Megawatt
NDA	Non-Disclosure Agreement
NEEA	Northwest Energy Efficiency Alliance
NEM	Net Energy Metering
NG	Natural Gas
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

1. Summary

Southern California Edison (SCE) submits this 2020 Q3-Q4 semi-annual report in compliance with Ordering Paragraph (OP) 59 of the California Public Utilities Commission (CPUC) Demand Response Decision (D.) 12-04-045, dated April 30, 2012. The subject Decision directed SCE to submit a semi-annual report regarding its demand response (DR) Emerging Markets and Technology (EM&T) projects by March 31 and September 30 of each program year.

As described in SCE's 2018-2022 DR program application (A.17.01.012, et al), and ultimately approved in D.17-12-003, the SCE DR EM&T program facilitates the deployment of innovative new DR technologies, software, and system applications that may enable cost-effective customer participation and performance in SCE's DR rates, programs, and wholesale market resources. The program funds research demonstrations, studies, the assessment of advanced DR communications protocols, and conducts field trials and laboratory tests. These activities help enable the innovative high-tech and consumer markets to adopt DR methods and standards that advocate for continuous improvement in DR technological innovation.

The SCE Engineering Services group in the Customer Programs and Services organization oversees the EM&T program's activities, and the program funds its activities through a portfolio investment approach designed to provide maximum value for SCE's customers. The program 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 for stakeholders DR-enabling technology education, in-situ field testing, capture of customer perspectives, understanding of market barriers, promotion of technology transfer, and, ultimately, customer and program adoption.

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

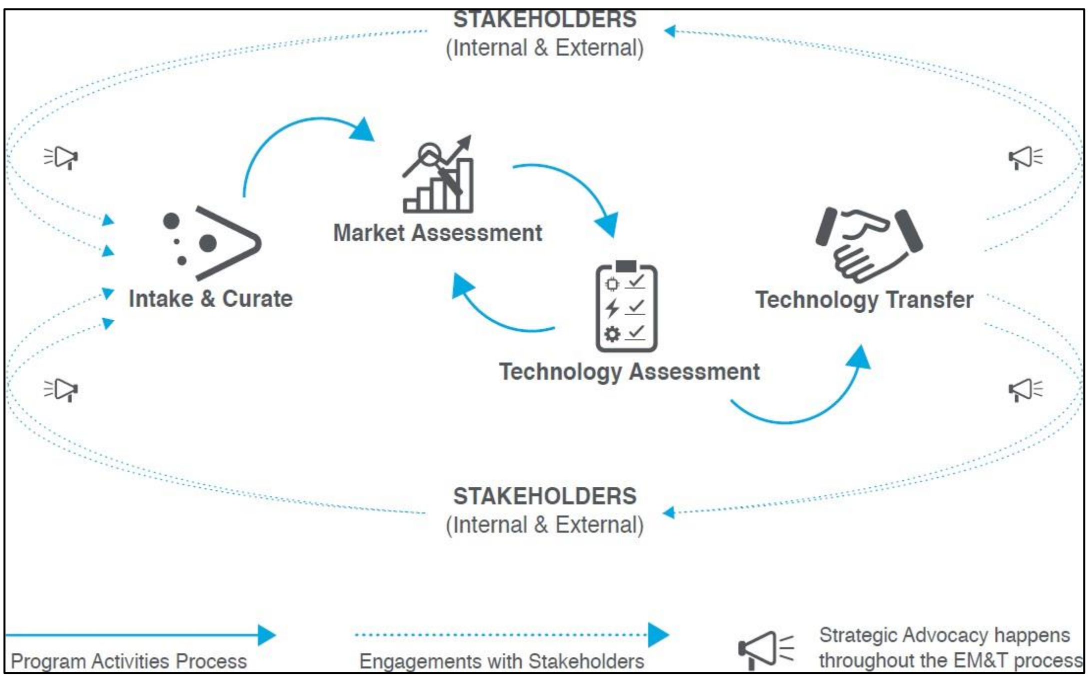
- Intake and Curation: Identifies studies, projects, or collaborations for inclusion in EM&T's portfolio and selects which ones to fund based on a well-informed understanding of the broader industry context.
- Market Assessments: Create a better understanding of the emerging

innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices.

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

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

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



EM&T Program's Current Portfolio Investment Approach

The following table lists the EM&T projects in this report that were initiated during Q3-Q4, 2020, as well as in-progress projects. Due to COVID-19 delays in 2020, there are currently no projects that were completed so none are included in this Semi-Annual Report. The table also identifies each project with the singular or bundled core EM&T Investment Category that each project addresses to facilitate the continued development of DR emerging technologies:

Project ID	Project Name	EM&T Investment Category
In-Progress Projects		
DR20.02	Wedgewood Demand Flex Testing	Technology Assessments Technology Transfer
DR19.08	Grid Responsive Heat Pump Water Heater Study	Technology Assessments Technology Transfer
DR19.07	Measuring Builder Installed Electrical Loads	Technology Assessments Market Assessments
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
Initiated Projects		
DR20.03	DR Technology Enhancements	Technology Assessments Market Assessments

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

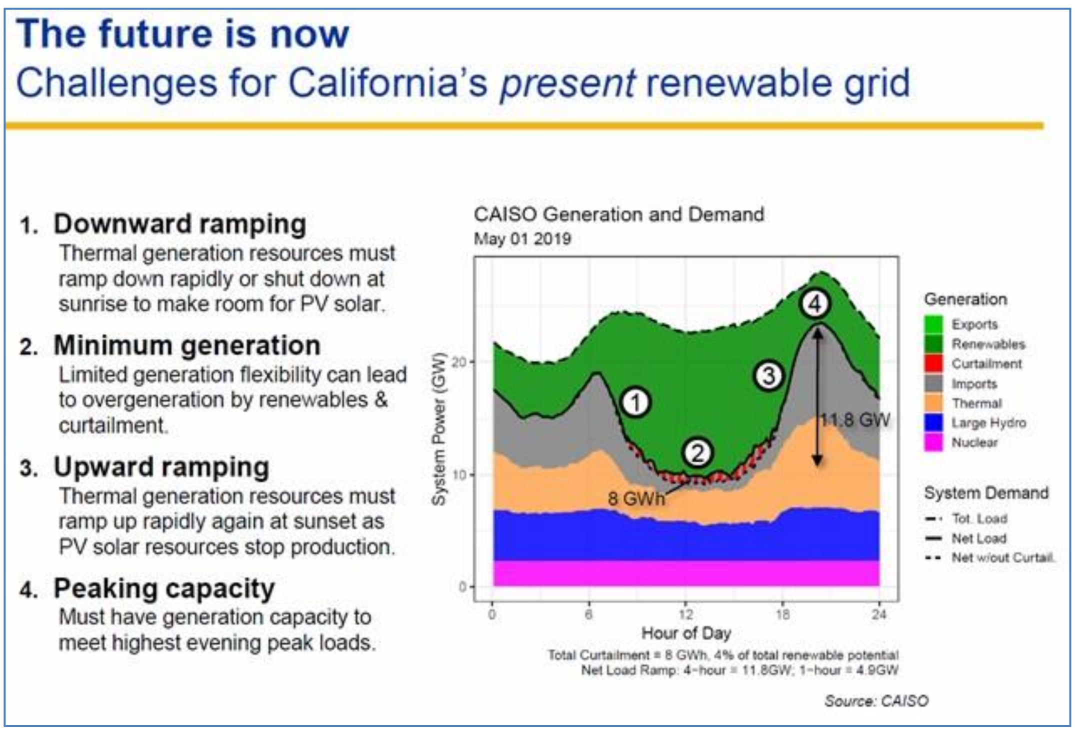
In accordance with the CPUC direction for the reporting of the DR EM&T program, this report covers SCE DR EM&T project activities during the timeframes between July 1, 2020 and December 31, 2020, for Q3 and Q4 of program year 2020.

2. Projects Continued Q3 – Q4 2020

DR20.02 Wedgewood Demand Flex Testing

Overview

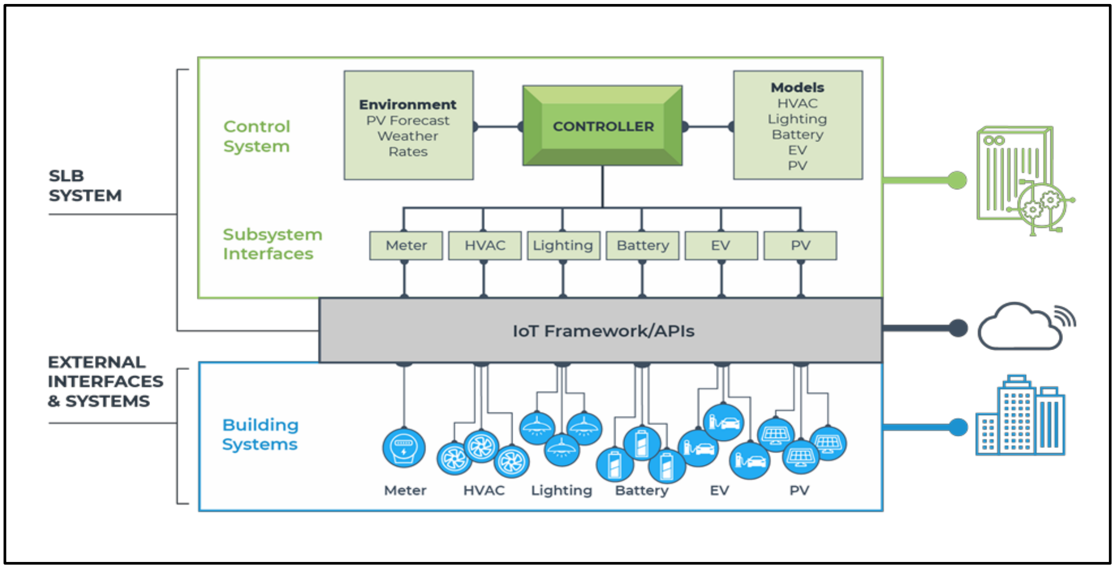
The ability to shift loads without significantly impacting tenant comfort is key to California's ability to address California grid challenges. The grid obstacles include power intermittency, demand peaks, and localized capacity resulting, in part, from rapid growth and scaling of customer self-generation, behind-the-meter storage, and intermittent loads such as new electrification loads and EV chargers. Smart buildings are needed to compensate for differences between forecasts and actual loads. Recent work by LBNL in its DR Potential Study confirms that the load-resource balance is already increasingly difficult to maintain on sunny spring days.



California's Future Renewable Grid Challenges

While the issues of ramping, "duck curve," and curtailment of renewables have been discussed for years by planners and operators throughout California, progress has been slow in developing technologies and programs that directly address these issues. In the meantime, solar deployments have continued at a rapid pace. More and more customers are adding both solar and storage "behind-the-meter", in efforts to manage their energy costs and ensure reliability in an uncertain energy future.

At the same time, the combination of behind-the-meter distributed energy resources (DER) and advanced system controls have been shown to be intelligently controlled to better manage customer loads in order to participate in traditional load shed programs, or to conform to emerging time-of-use rates and other emerging energy pricing signals. For example, there are current software systems designed to use predictive algorithms that optimize loads based on predicted and actual weather and solar generation. These systems are thus able to manage customer loads in concert with the needs of both the grid and the customer's operations.



Intelligent Load Balancing Software Illustration

The Wedgewood Demand Flex Testing Project will evaluate the energy and non-energy impacts and benefits of using an innovative load management software platform. This software will optimize the commercial building's HVAC operations in coordination with the building's onsite generation system of solar power. The study will be conducted at an 83,000-square feet commercial office building located in Redondo Beach, California. The facility has two floors with over 500 employees working across nine different businesses. The site has a 625-kW solar PV system installed on its rooftop and on top of carport canopies in the parking lot. Major end-use energy consumers at the facility are heating ventilation and air conditioning (HVAC) equipment, electric vehicle (EV) charging stations, lighting systems, and other miscellaneous loads.

The Wedgewood campus has a combination of factors that are favorable for electric load optimization techniques and Demand Response capability, as follows:

- Solar PV production accounts for a sizeable portion of the facilities' total energy usage due to the size of the system.
- The facility is on TOU rate structure TOU-GS-3 Option E (previously TOU-GS-3 Option R) allowing for shift opportunities.
- Fixed operating schedules provide an opportunity for time-based optimization, reducing variability in the machine learning algorithm.
- System Demand Response capability is fast and flexible and can increase or decrease power many times each day relatively quickly.

Wedgewood Building Demonstration Site

In a phased approach, the Wedgewood Demand Flex study has developed a set of research hypotheses which will evaluate the ability of the software to modify the Wedgewood HVAC operations in two ways, shown below, to support current and future California and SCE DR programs and load management initiatives:

1. Load Shift Hypothesis: First, can the software effectively reduce the customer's HVAC-related demand charges by between 10% and 25%, without negatively impacting building tenant comfort, by shifting operations and increasing loads during SCE's non-peak TOU periods, and reducing loads during peak periods?

2. Load Shed Hypothesis: Second, by driving a deeper level of HVAC setback than under normal operating conditions, can the software enable two to four hours of load shift of at least 20% of whole-building load in response to simulated day-ahead, hour-ahead, and 15 minutes-ahead load curtailment signals from SCE?

The intelligent software system was designed to reduce a customer's peak demand by shifting energy use from more costly demand periods to periods when the building's solar PV panels are generating power, using its algorithm based on forecasted and actual weather conditions. Under this scenario, and the customer's current rate schedule (TOU-GS-3-E), the software is expected to reduce customer demand costs between 10% to 25%, while minimally impacting tenant comfort. The team will examine the M&V (Measurement and Verification) results of the reduced customer demand and costs by shifting energy use from more costly demand periods to periods where the building's solar is predicted to be generating power, based on predicted and actual weather conditions. Full data analysis of the load and the efficacy of the load management system will be examined and reported.

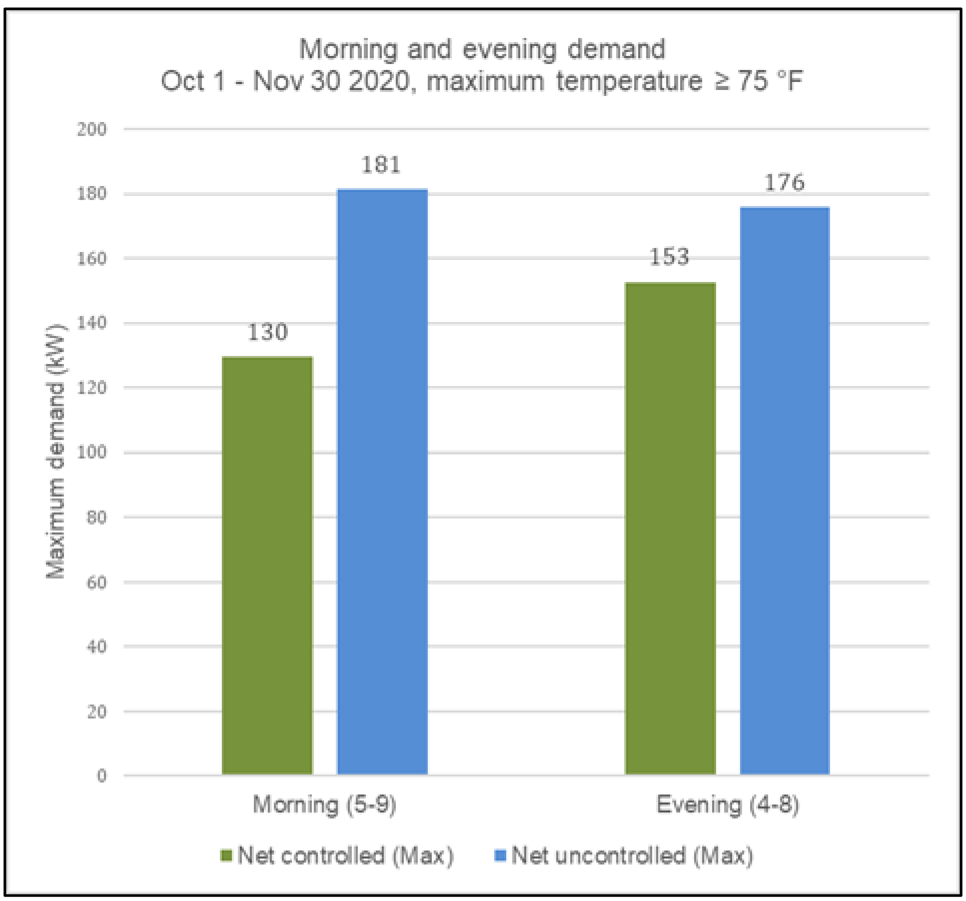
The project was funded under the EM&T Technology Assessments and Technology Transfer investment categories, as there are elements of both research goals in this study. The Technology Assessments category assesses and reviews the performance of DR-enabling technologies through lab and field tests and 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 team has engaged Alternative Energy Systems Consulting (AESC), Incorporated as the lead contractor, and Extensible Energy is providing the DR management software platform by working with the Wedgewood facility team for system integration. SCE is also sharing the scope of this work with its partners within the ETCC and other research organizations to provide advisory services and technical review. While the building owner at Wedgewood is conducting an equipment upgrade at this facility and leveraging energy efficiency funding, no DR co-funding or cost-sharing with other utilities, private industry, or other third-party groups for this project was requested or received.

Results/Status

The project to date has demonstrated that significant demand reductions at the demonstration site can be achieved during peak demand times through load shifting. Demand was reduced 15.5% on warmer days when cooling was needed, with reductions of 28% in the morning and 13% in the evening (see the figure below). In addition, the control software was able to reduce energy consumption in the evening hours by 19%, while compensating with increased energy consumption in the afternoon when there is substantial renewable solar generation. Additionally, the system was able to shed load of approximately 14% compared to the maximum observed peak demand for the one-hour DR test.



Morning and Evening Demand Reduction due to Control on Warmer Days (Maximum Temperature ≥ 75 F)

If deployed at multiple sites and at scale, this demonstrated load-flexibility could provide a significant demand shifting benefit for utilities, integrate renewable resources into the California grid, and potentially add significant direct utility cost savings to the site customers. In addition, the ability to shift demand from periods with less solar generation into periods with more solar generation would support the state's policies for reducing emissions from fossil-fueled generation.

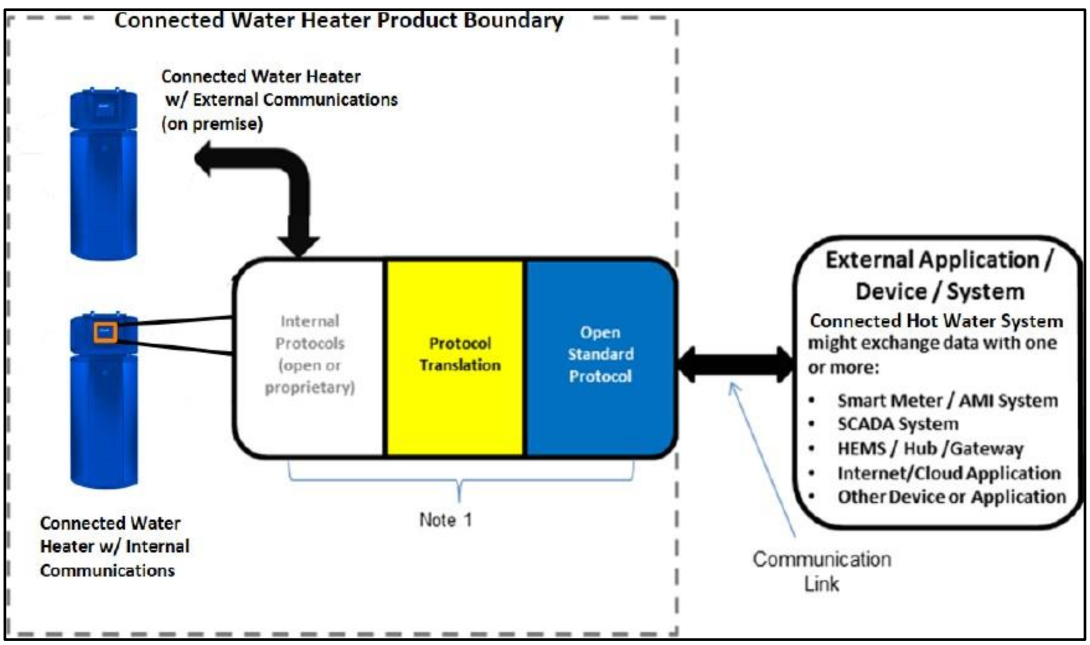
Next Steps

All field project activities have been completed and remaining data analytics and findings are being incorporated into the development of the final draft report. The SCE project staff will initiate review of the final draft report submission and project closeout presentations. The final report is planned to be submitted for review in early Q2 of 2021.

DR19.08 Grid Responsive Heat Pump Water Heater Study

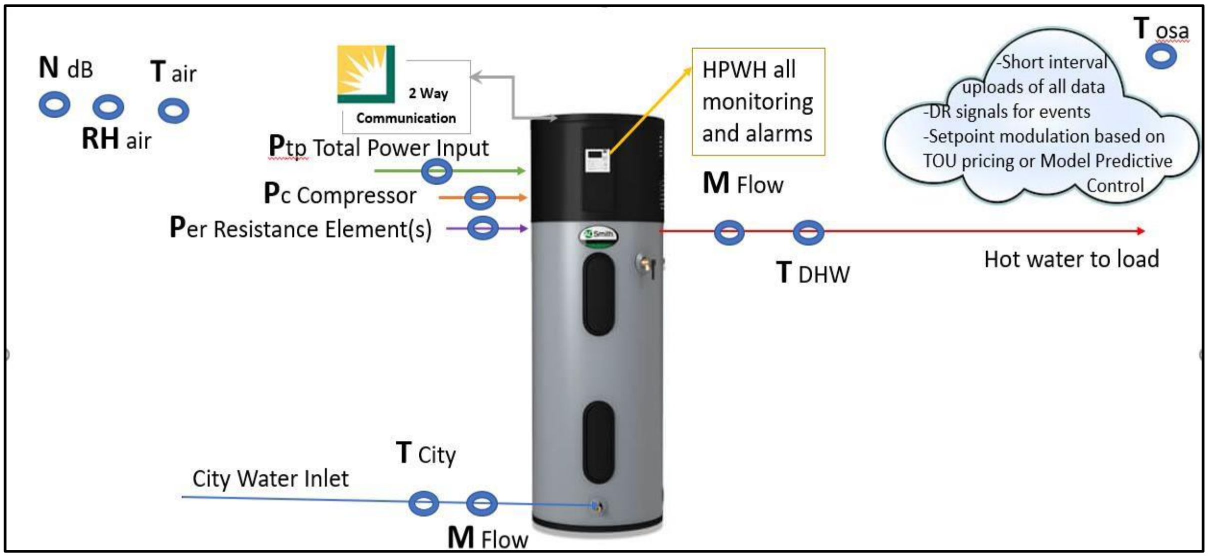
Overview

SCE's Emerging Technologies Program (ETP) and Emerging Markets and Technology (EM&T) Program have been conducting 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 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 SCE pilot will provide 150 qualified single-family homeowners in three SCE communities opportunities to replace their propane water heaters with HPWHs to reduce overall energy costs and improve the health, safety, and air quality of the residents in those communities. Twelve (12) of the 150 HPWHs will have 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 study is designed to address the following research issues:

- Assist SCE in understanding integration of renewables and load dispatch as well as help 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 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.

- Help inform how hot water storage over various time frames can be used to add load or shed load. The research will provide results that should enhance SCE and other stakeholders' understanding of integration of renewables and load dispatch. This will include detailed monitoring and analysis of the technical performance of HPWHs, including grid benefits and grid impacts of 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 will have a garage for the HPWH and no recirculation system. The 12 homes are part of a larger pilot of 150 electrified homes deployed with the pilot to electrify homes and reduce emissions within the SJV. The prime General Contractor (GC) and Community Energy Navigator (CEN) of the larger project will be responsible for the customer selection and the selection and installation of the grid-controlled HPWH and a proposed communication package to be used by SCE for the grid responsive signals. SCE plans to minimize the risk of any failures of the technology that might occur at the customer home; therefore, the HPWH controls and the grid-responsive communications technology will first be functionally tested in a laboratory environment prior to deployment in the homes.

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

Collaboration

The research team consist of SCE’s Engineering Services group under the direction of the ETP and EM&T program managers and will be assisted by SCE’s technology consultants. The SCE Income Qualified Program group will oversee the SJV DAC and will work with the research team to select the customers for the study. Community leaders from the San Joaquin Valley and the communities of California City, Ducor, and West Goshen will also be involved. The project is jointly funded by the EE, DR, and the Energy Savings Assistance (ESA) and California Alternate Rates for Energy (CARE) programs. The EM&T program is only funding a portion of this 12-home study for the development of the specific demand response research outcomes.

Results/Status

Following project delays due to COVID-19 restrictions in 2020, the SJV Disadvantaged Community (DAC) Pilot project has now begun homeowner recruitment. Over thirty site assessments have been completed and four sites have appliances installed, significantly below the planned target levels for the Pilot. The SJV DAC Pilot is currently focusing activities in the cities of Ducor and West Goshen only. The research team is collaborating with SJV installers to determine suitable sites for the 12-home study and coordinating a research approach aimed at "low impact" to the participants in the main SJV DAC Pilot activities. The research team developed the instrumentation plan for the study and is procuring instrumentation and data acquisition equipment while customer recruitment progresses.

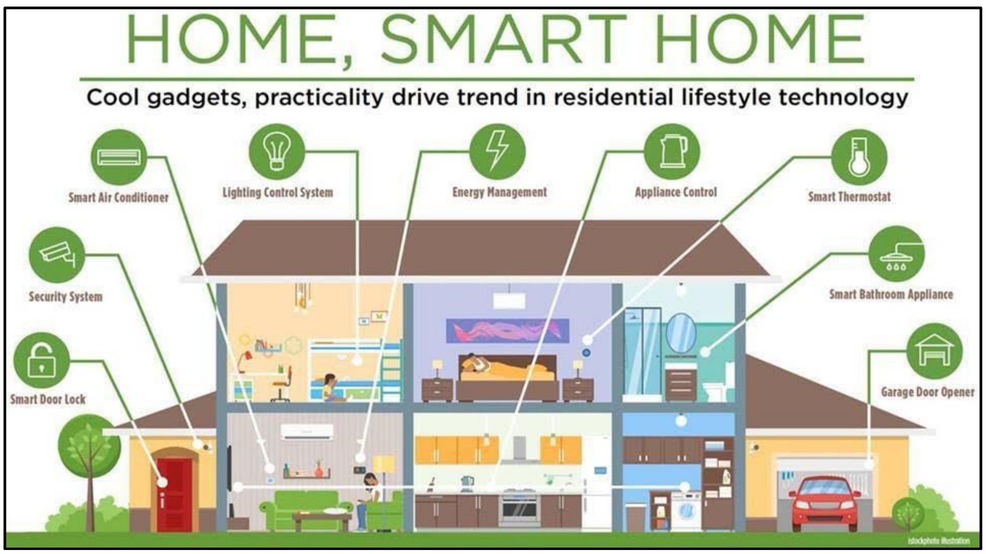
Next Steps

SCE is planning to continue its collaboration with the SJV DAC Pilot team and the contract field installers to select the twelve suitable HPWH research sites, and coordinate installation of instrumentation and data acquisition equipment in alignment with the SJV DAC Pilot customer recruitment activities. The overall impact to the project schedule and timing of the data collection due to the COVID-19 restrictions may continue to slow the HPWH research activities with the overall schedule effects yet to be determined.

DR19.07 Measuring Builder Installed Electrical Loads

Overview

The home builder/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.

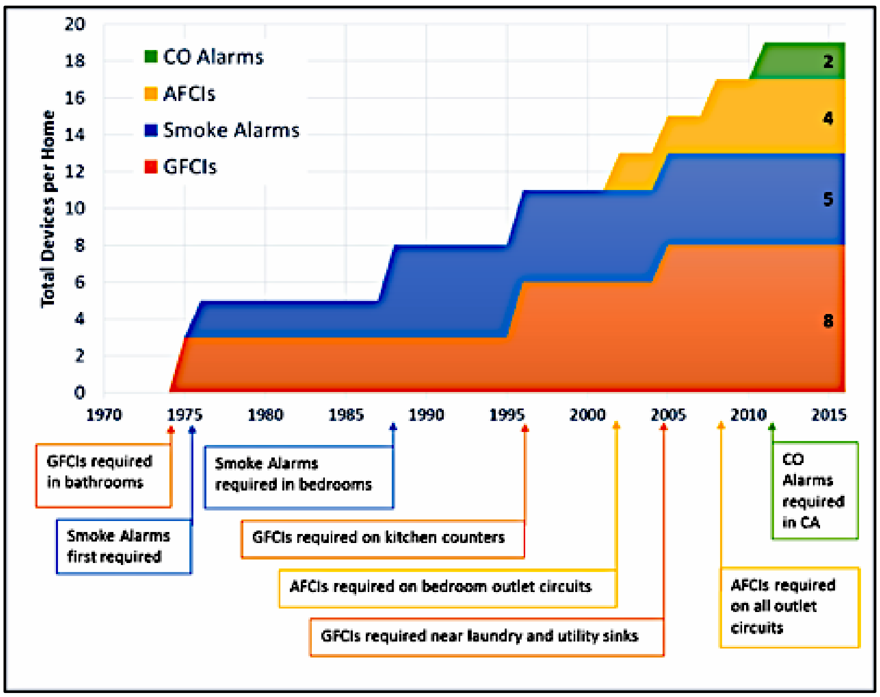


Smart Home Technologies Illustration

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:

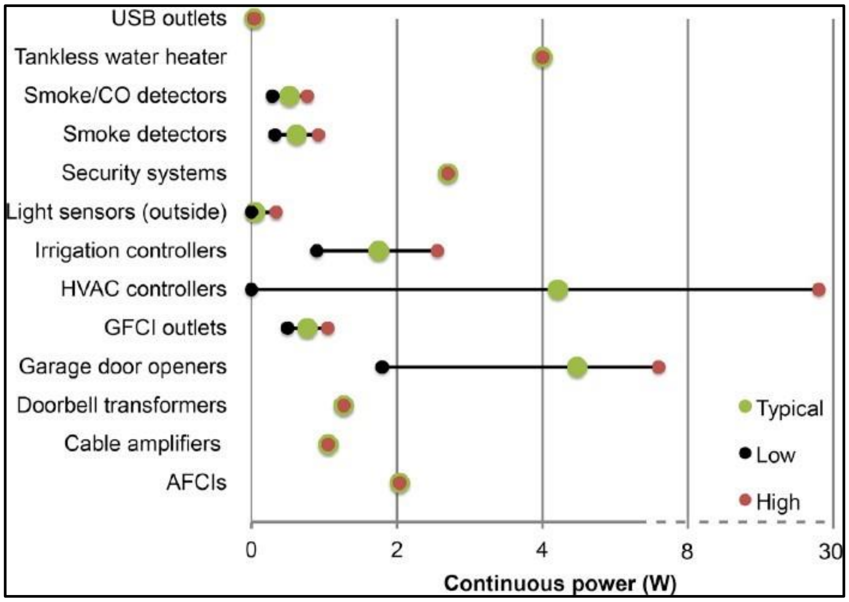
- Examine opportunities for load management (shift and/or shed) of new construction hard-wired loads that could possibly be managed to reduce their small but growing impact on future overall residential energy load shapes and ultimately GHG emissions.
- Develop anticipated new load shapes and energy 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 is to collect data on electricity consumed by equipment in newly constructed homes. Short-term, whole-house power measurements will be taken from new homes during a relatively short time period between the completion of construction and move-in of the homeowner. The research team will identify builder-installed electrical devices found in new, smart homes in California and other relevant locations. The team will collect bills of materials and information about actual construction practices in new homes. Focus would be on non-standard appliances and devices (that is, not air conditioners, refrigerators, lights, etc.) and all-electric homes. The team will prepare a list of devices and their technical characteristics. This includes estimating the power draw, load shapes, and energy consumption based on nameplate, laboratory measurements, and literature surveys.

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



Summary of Typical Builder Installed Loads

In the next phase of the project, the research team will create a model of prototype home data that can hold builder-installed device data and perform simple calculations. This will include home information such as floor area, and device characteristics such as load shape and demand shifting opportunities. The team will create five "smart home" prototypes with builder-installed devices based on the bill of materials. The team will then calculate the contribution of the builder-installed devices to the home's power draw, energy consumption, and load shape.

For a specific assessment of the demand response potential, the team will investigate the gross load impact of builder-installed devices, calculate the whole- house load shape for each prototype, and evaluate the load shifting potential of individual builder-installed devices, with an emphasis on dispatchable devices and possible interaction with either EV smart inverters or installed energy storage.

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

Collaboration

This project includes collaboration with internal SCE groups, including Emerging Technologies and the Business Customer Division. Stakeholders have an interest in finding demand responsive solutions for builders that will make the homes they construct less energy intensive while managing loads to minimize grid impacts. The study will be conducted with researchers located at the advanced buildings section of the LBNL facility, EPRI, and coordination with builders through SCE field services. The project is being co-funded by the SCE Emerging Technologies program and as a member of EPRI, SCE is also co-funding parallel research investments with other utilities and leveraging that research to assist in this study, but no other direct cost -sharing or co-funding with any other parties was enabled.

Results/Status

Originally, the project approach incorporated a strong focus on in-situ field measurements of the Builder-Installed Electrical Loads (BIELs). Due to COVID-19 restrictions, the approach to collect on-site data at new home developments was determined unfeasible, and the project scope was modified to place more emphasis on academic peer research and modeling, with plans to incorporate laboratory and alternative field measurement activities. Additionally, more emphasis was placed on the investigation of "smart" BIELs, such as solar inverters and EV chargers. While the core objectives of the research are still in focus, the modeling and peer research will be developed as substitutes for the field work, as access to new construction homes is no longer in scope.

A technical memo was developed in Q3-Q4, capturing the research study findings on BIEL technical characteristics. The paper study was comprised of literature surveys, info gathered from smart home builder websites, technology publications, manufacturer websites, ENERGY STAR-qualified product lists, interviews, and builder-supplied documents. A BIEL device library was also established as a living document, detailing energy and power consumption, the expected types and numbers in a typical home, and other relevant characteristics. Over 100 devices were reviewed, and over 35 smart BIELs were identified.

Next Steps

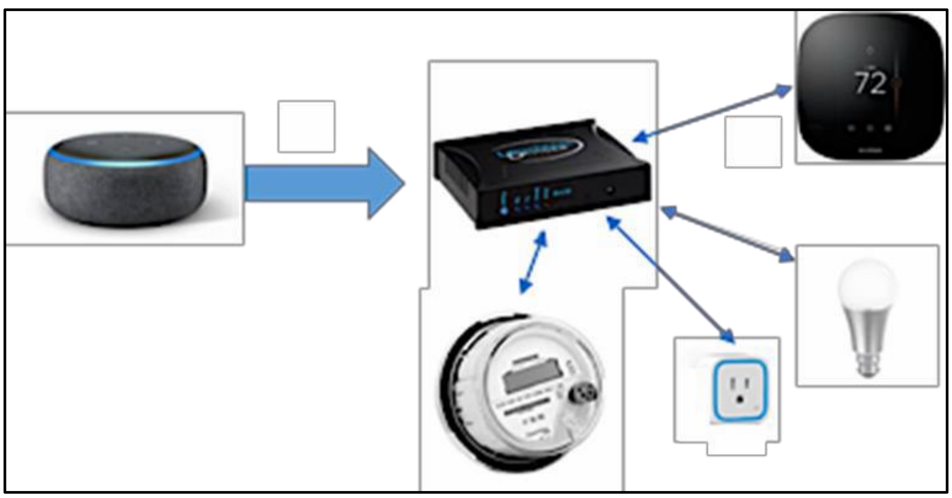
The team will next focus on characterizing the overall energy usage patterns and breakdown of energy consumption by BIEL device through energy modeling of several identified prototype home models. Updates/refinements to the prototype home models characteristics will continue in 2021, and direct/indirect demand/energy impacts will be simulated, verified with lab and field measurements where possible as the team adjusts its approach. The team also plans to continue to provide a technical forecast for the demand response potential of such smart homes to ultimately help SCE identify opportunities for load shifting, demand response, and energy savings with the new anticipated home technologies.

DR19.03 Smart Speakers

Overview

Virtual voice assistant devices such as Amazon's Alexa 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 are becoming exceptionally popular, and according to public market research reports, as of 2019, an estimated 35% of U.S. households were equipped with at least one smart speaker. By 2025 the adoption rate is expected to increase to 75%.

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 both connect with customers (such as 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

As customers are changing their digital interactions with utilities — especially within the connected home arena — SCE wanted to explore 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 are to:

- Better understand how connected smart thermostats and other "smart" household end-uses 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 — can 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 are to:

- Better understand how customers can effectively interact with and use the smart speaker and other connected technologies in the home, for 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 will receive 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 are adjusted to run less during peak times. This project will demonstrate the smart speaker's interactive capabilities with household occupants and will assess whether the smart speaker can enable customers to manage their energy use and cost by optimizing all their connected devices.

The project will use a meter-based assessment that is individualized for each home to assess impacts of energy savings, load shifting, and load reduction. The goal will be to understand energy usage impacts and to potentially develop a deemed 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 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 leverages 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 is 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 leverages over $3M of funding. The M&V study to assess the load impacts or price elasticity effects will be conducted by Nexant under contract to SCE. No other direct cost-sharing or co-funding with any other parties was enabled.

Results/Status

Customer site visits and installation activities were completed in Q2 2020, and no additional installation activities were performed in Q3-Q4 2020. A total of 74 customers were confirmed as active participants. The project team compiled documentation and preliminary information from the activities of the initial rollout of the Amazon Alexa Energy Expert skills and initiated measurement and verification (M&V) activities. The project’s M&V team procured interval usage data to begin analysis on the “first-phase” impacts of the Smart Speaker project demonstration and is slated to present these results in early Q2 2021.

Additionally, “first-phase” activities identified a near-term opportunity to explore further refinement of the Amazon Alexa Energy Expert skill-set: to incorporate use of SCE Green Button data to enable participants to engage in billing and rate related inquiries. Feasibility of Green Button functionality was explored, and incremental skills were successfully developed and tested. Customers will be able to authorize Green Button functionality to enable the following inquiries:

- How much is my bill?
- How much is my bill compared to this time one year ago?
- What rate am I enrolled in?

- Am I on the best rate?

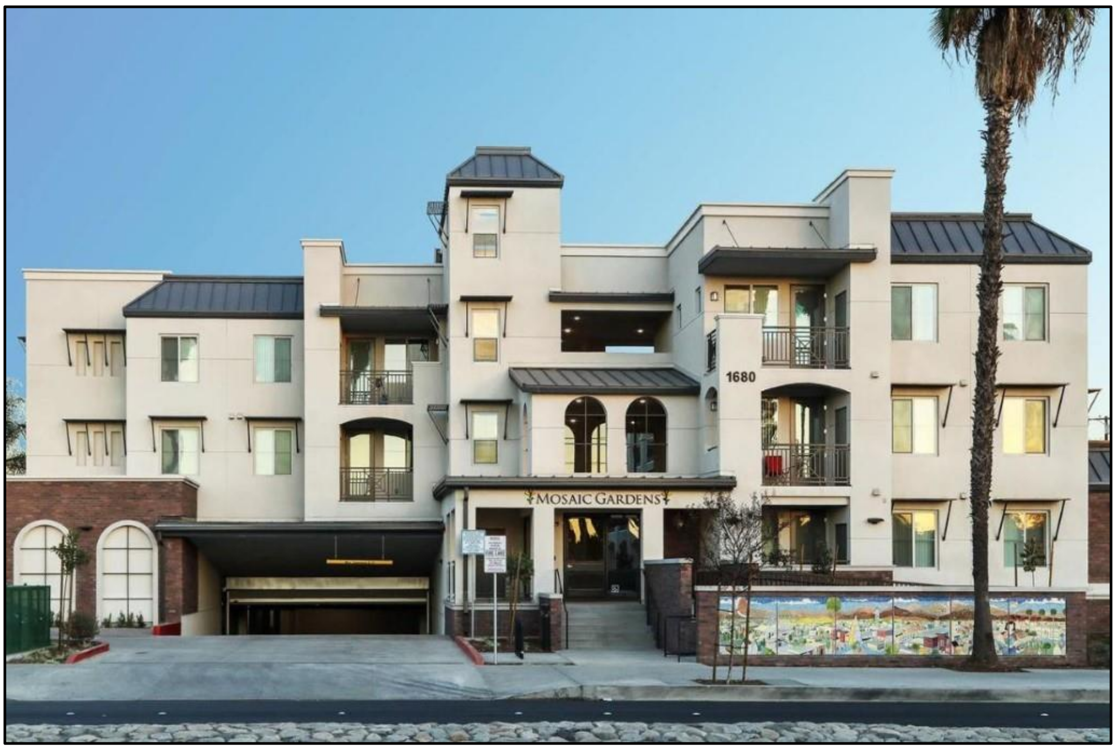
A ”second-phase” rollout of these skills and re-engagement of participating customers is targeted for Q2 2021.

Next Steps

The research team will conduct a “second-phase” re-engagement with customers and rollout of smart speaker skills in 2021 that will give participants the option to authorize Green Button-enabled functionality for billing and rate related inquiries. A second customer survey has been drafted and will be finalized and issued at the end of the second phase (Q3-Q4 2021). The project team is slated to finalize all M&V activities in Q4 2021 and to draft a final report at that time.

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 is designed to assess 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 Multifamily Low-Income Facility

This project is designed to provide 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 has been 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 proposed project endeavors to characterize the changes in the building's load shape and grid impact qualities associated with behind-the-meter (BTM) customer-sited energy storage.

The project will give SCE 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 will be primarily on storage acting as a DR resource.

Battery Energy Storage System in Multi-Family Building

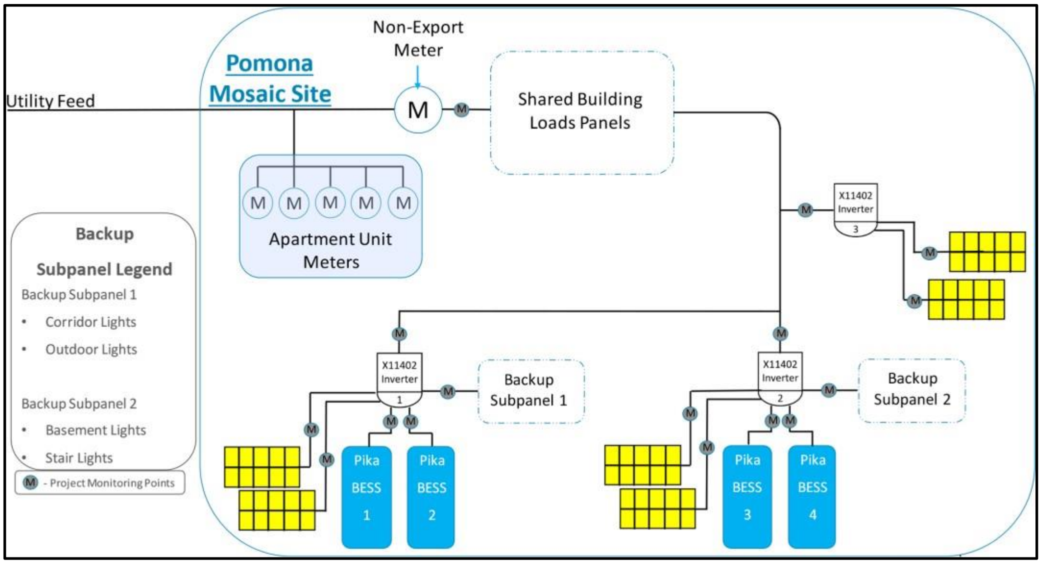
To enable the DR operation of the battery storage system, the project will leverage previous BESS research to gain a comprehensive understanding of the system's performance and its benefits and impacts for the customer and grid operator as a possible new DER resource. The planned study will provide in-field case studies for SCE and its technical stakeholders for the 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 can provide 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 seeks to understand how these systems can:

- Create incremental grid value in locations with demonstrated needs (e.g., 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 will be accomplished by first developing a detailed test plan which will characterize the energy storage system itself, as well as grid service-based operations and customer service-based operations. Several dispatch strategies will be examined, as well as assessing which secure communications approach and set of protocols are applicable.

The specific assessment of the energy storage system as both backup and as a distributed energy resource (DER) will include characterization of round-trip efficiency, battery module degradation, depth of discharge, and power capacity at variable states of charge. Grid service characterization will cover 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 primary objectives of this project are to demonstrate how customer storage can be leveraged and to quantify impacts to both customer and grid stakeholders. The research focus will cover 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:
    - o Control and communication, both local and remote
    - o 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 will be executed in several phases. It begins with the completion of the battery and solar interconnection and proceeds to design validation to ensure interconnection was completed as intended. Any issues found are reported and repaired, issues can be used to guide SCE's future work with customer-sited energy storage, and M&V can be achieved accurately. The research team will also advise on appropriate installation techniques, including appropriate metering to achieve project objectives and the appropriate choice of backup loads chosen to ensure appropriate results. This will help to achieve test objectives, while providing the customer facility with resiliency during power outages.

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

Collaboration

This work is 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 is an active and supportive participant in the work. The Electric Power Research Institute (EPRI) is supporting 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 are funded by the EM&T program, SCE is leveraging 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 BESS installation contractor (Promise Energy) needed to make modifications to the M&V design and include additional monitoring equipment in mid-2020 in order to receive

Self Generating Incentive Program review, as the approval for Permission to Operate (PTO) was previously attained. These additions also enabled the use of additional advanced control monitoring to facilitate the testing criteria established by K&A and EPRI. COVID-19 restrictions delayed the installation of additional equipment required for the EPRI work and slowed progress through the end of Q3 of 2020.

The BESS and associated solar system are currently operational at the site and some limited round-trip efficiency tests have commenced. During the initial battery tests during Q3-Q4 2020, it was determined that the inverter cores should be upgraded to the latest Generac cores from the original PIKA cores. This core replacement was accomplished by the end of Q4 under warranty but impacted the test schedule with further delays, as travel and access were limited until California COVID-19 restrictions allowed for more detailed site visits for all personnel.

Highlights from testing the BESS include:

- Round trip efficiency testing indicates battery efficiency, available power at varying states of charge, and capacity degradation over time.
- Thermal impacts of battery operation and environment can impact reliability of individual and aggregated systems in the field.
- Time to full discharge indicates the capability of the BESS to back up essential building loads as well as provides opportunity to support the grid through peak pricing time-of-use scheduling.

Next Steps

EPRI and K&A are planning to continue the battery testing going forward in Q1-Q2 2021 utilizing the planned test criteria previously developed in a customized test plan. This effort will complete the M&V design, installation, and commissioning of the auxiliary BESS monitoring and verification equipment in collaboration with the BESS vendor, the installing contractor, SCE’s interconnection group, and the building owner, LINC Housing, under the current COVID-19 safe work practices. The testing data will be provided to the Self Generating Incentive Program inspector in order to pass the field verification and to successfully attain approval to enable the customer to receive SGIP incentives.

The EPRI/K&A team developed the BESS test plan based on the facility capabilities and interests of the SCE EM&T and T&D engineering staff and have been working with LINC to facilitate the on-site BESS testing, M&V, and operational changes. The full implementation and testing of the system were expected to be completed in late 2020; however, a new adjusted schedule is being developed and testing that commenced in Q4 2020 will continue through 2021. The continued testing effort will entail assessing the community backup power and resilience capabilities, economic characterization and analysis, qualification of efficacy of operation, developing a framework for scalable BESS analysis, and recommendations of modifications to improve control and operation of the BESS. A draft interim report is targeted for Q3 2021, and the final report deliverables are expected to be completed in Q2 2022.

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

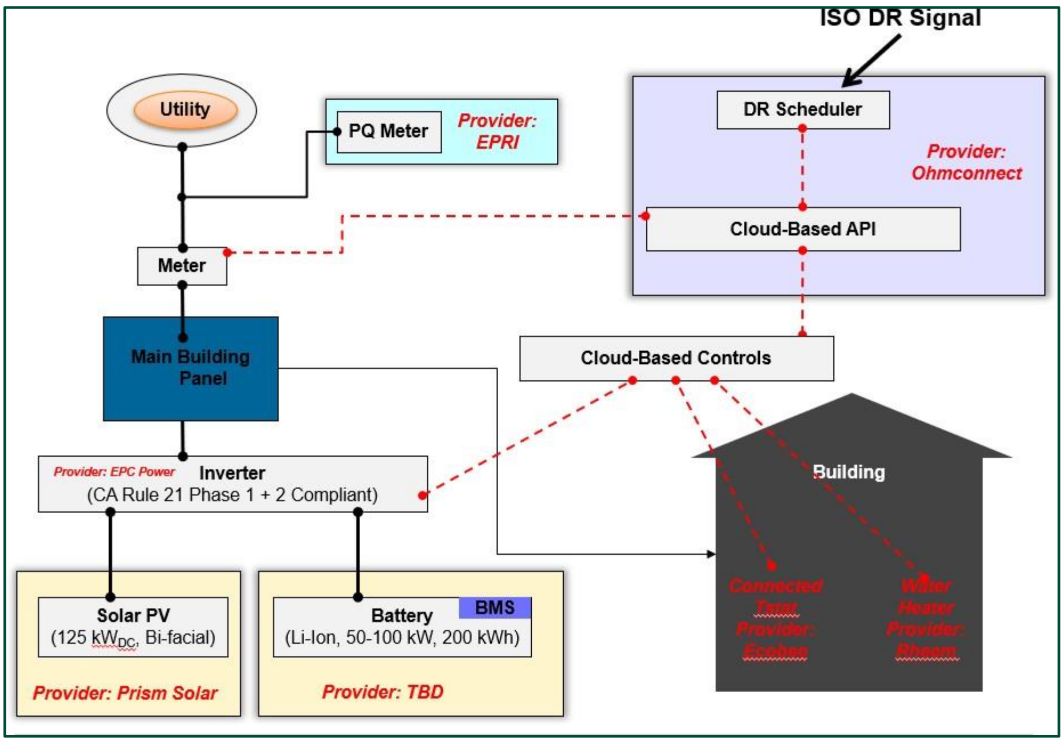
Overview

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 showcases 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 are being installed at this site with a target efficiency of about 23%. The project is studying use of a DER integration platform that is communications agnostic. The multi-port storage arrangement with smart inverter configurations enables a "shared savings" model. Relevant M&V efforts will include a comparison of pre- versus post-treatment energy utilization, disaggregated by end-use as well as feedback on the customer experience. Many customers will be 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, is also looking at developing and implementing 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 being demonstrated include:

- 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 will be 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 will be examining 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 will be investigated in this project, as part of the overall DER design in the building. Specifically, EPRI will be examining how the bifacial PV and DC microgrid can be optimized with the DER integration platform that will receive CAISO dispatches. The goal of that effort is 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 DSO, and optimize the aggregated system's dispatch and control for stacked value at the customer and grid level.

The project team also plans to investigate 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 is to demonstrate a cost-effective solution for achieving Zero Net Energy (ZNE) within an affordable housing community, and thereby realize California's 2020 goal for new sustainable and scalable ZNE communities.

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 funding the DR portion of the project through an EPRI Supplemental Program Agreement (SPA) as a co-funding commitment to a larger CEC grant. The overall project is being designed and operated by EPRI under a contract with the CEC's EPIC program. Other partners include LINC Housing, Canadian Solar, E-Gear, GridScape, EPC Power, Staten, 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 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 enabled.

Results/Status

The CEC had issued a Stop Work Order (SWO) to EPRI due to project delays from the building owner. However, the issue was remedied and the SWO was lifted on August 20, 2020 which allowed the project to continue construction and for the schedule to get back on track.

In Q4 2020, the solar PV was installed on both the sloped roofs of both buildings and the flat roof where the ballasted panels have access to optimum bifacial solar gain. The dual inverters were installed on both buildings, as well as the DER integration platform. Additionally, the battery energy storage systems were installed, and all the necessary wiring was completed to facilitate the testing of the integrated systems. As of the end of Q4 2020, all solar and storage construction was completed.

Next Steps

The systems will be commissioned by EPRI with SCE present as a part of the approval process. Los Angeles County inspections for the electrical, mechanical, fire, and whole building are pending. The project is now waiting for the SCE installation of the Net Generation Output Meters (NGOM) at each building. The installation has been requested and it is being scheduled at this time. Once the NGOMs are set, then Permission to Operate (PTO) will be officially granted. The design of the DC micro-grid is being finalized and prepared for the submittal of plan check for the electrical and mechanical permits.

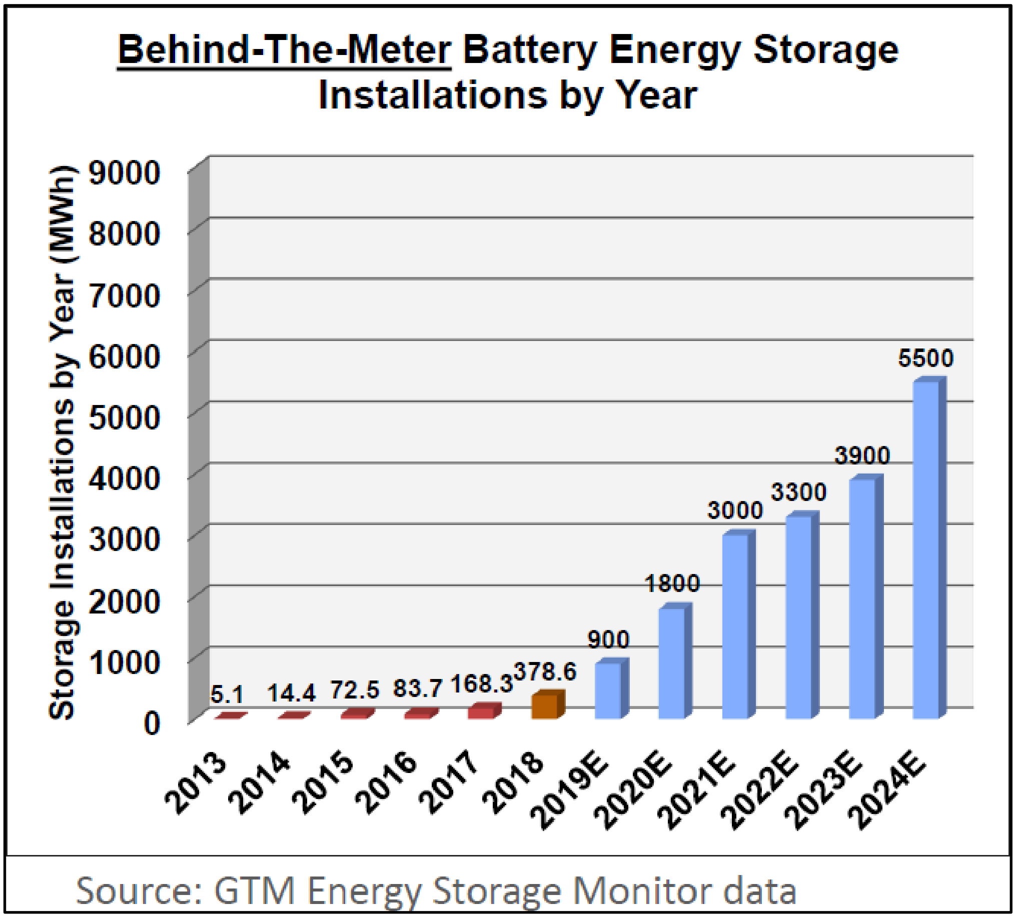
EPRI will also on-board residents for participation in the OhmConnect program. Only one-third of the residents have enrolled to date. OhmConnect software is being utilized to allow the tenants to receive a message to encourage conservation of on-premises HVAC, water heating, and plug loads and provide that load data to Open Demand Side Resource Integration Platform (openDSRIP) as a behavioral DR resource.

Measurement and Verification will begin in early March 2021, followed by a report on commissioning and implementation technology assessment. Additionally, a distribution system analysis, cost benefit analysis, customer value proposition of distribution grid services report will be completed in Q3 2021.

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.



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 a huge 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 has been 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 have been installed at three homes, and an additional unit has been installed in an SCE Smart Home. The proposed project allows for the extension of concurrent and previously established research 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.

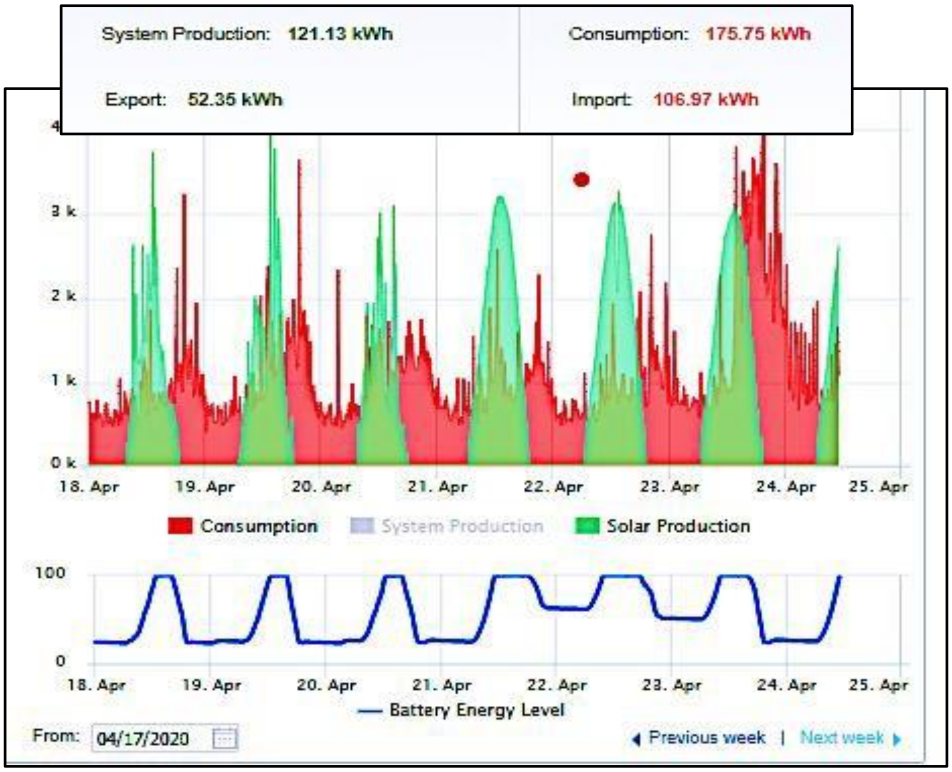
Residential Battery Storage System Under Assessment

Another goal of the project is to better understand how smart inverter APIs 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 will assess the performance of three residential lithium-ion batteries with SolarEdge smart inverters that have been installed and commissioned in the Moorpark area. The research will also address 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 will prepare 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 will develop a test plan that will examine 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, will examine 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 is leveraging three residential participants from a previous CEC EPIC grant project, who have allowed the battery energy storage system (BESS) to be installed by a third-party systems integrator. The BESS includes a SolarEdge smart inverter system and the LG Chem RESU battery panel installed by Promise Energy. Kliewer & Associates has 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 field testing work during the first quarter of 2020 was placed on hold due to COVID-19 restrictions that prohibited scheduled on-site customer engagement. The SCE project team subsequently secured licensing for an enhanced version of the BESS control APIs designed for aggregators (SolarEdge Grid Services) and is examining how the software can be managed for both remote scheduled BESS operation and customer real-time management. The project team secured safe work practice recommendations at the end of May 2020 and subsequently performed final BESS commissioning at all three sites, aligned BESS scheduling to the Prime-D tariff, and successfully demonstrated transactive load control response via remote charge/discharge scheduling.

Due to continuing COVID-19 restrictions in Q3-Q4 2020, the project team has been safely working to install Polisy home automation equipment at each of the customer sites which will enhance the ability to collect data to understand tariff and TOU rates for each customer. The project team coordinated with Universal Devices to implement Public Safety Power Shutoffs (PSPS) modes for the BESS by using Alexa smart tools and the smart speaker algorithm developed by Universal Devices for SCE's Smart Speaker project. Final inspections were conducted at all three customer sites to verify proper installations of BESS and customer surveys were distributed for feedback on BESS technology and smart tool integration.

Next Steps

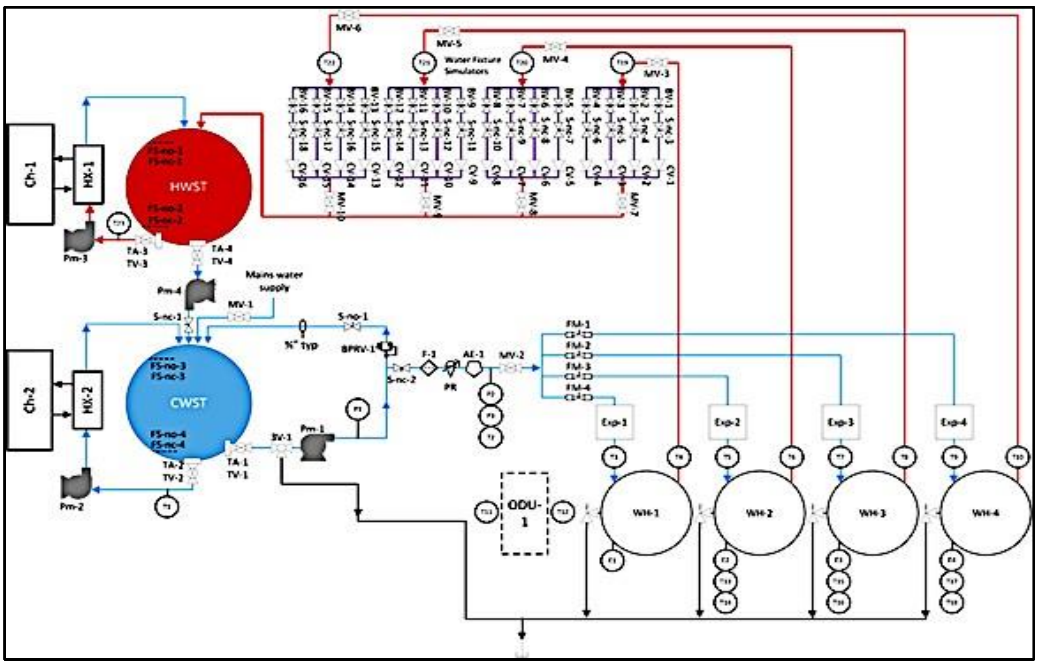
The research team plans to continue to collect data with remote programming of the BESS and site visits for inspections under safe work practices, and at the same time follow the most restrictive state, county, or local orders. SCE will use data developed via remote execution of the test plans to complete a final report detailing design validation, selection of use cases, test plan development and test plan execution.

The development of a final report that includes test plan results is planned for Q2, 2021. The research outcomes from this project will be shared with SCE and its technical stakeholders for the continued understanding of the technical capabilities of residential 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 mass market flexible assets.

DR18.04 Heat Pump Water Heater Systems

Overview

The project has been 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 is designing and constructing a Flexible DR Secure Communications Demonstration Lab for Water Heating Systems at the SCE Energy Education Center. The project will create a lab-demonstration for HPWH Open AutoDR testing using various transport media, and 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 (LDS-1A)

Much like an air conditioner, HPWHs use electricity to transfer (or “pump”) via a vapor compression cycle the ambient heat from the local environment. In the case of the HVAC system, the air is cooled by removing the heat from the internal space. For a HPWH, the water within the storage tank is heated by transferring the heat from the local environment, instead of heating the water directly (as through resistance coils in an electric water heater). Through this compression cycle heating mode, HPWHs are two to three times more energy efficient than conventional electric resistance water heaters. However, these systems are also equipped with resistance elements (coils) as backup, which can be activated during periods of high hot water demand or if the ambient temperature is low. The units can also be deployed in a "negative" demand response mode, meaning if the electricity rate is very low (due to excess renewables at the market level), the HPWH can act as a "take" to heat the water, and thus acts as a "grid responsive" end-use load. This type of operation has not been well demonstrated, and so SCE initiated this project. The test plans include case studies for customer-to-grid integration scenarios to examine how HPWHs can react to dispatch and shift signals and the effect on temperature from water draw during times of high- and low-water usage.

Typical Residential HPWH Installation

The HPWHs in the SCE Lab will be modified, if needed, to be converted to a grid-responsive device by either adding a two-way communication device or accessing the existing communications module within the system. This will allow the HPWH to be controlled remotely by SCE. The communication device can signal the HPWH to increase the thermostat temperature control during low-electric consumption times and will lower the water heater thermostat control during high-energy consumption periods throughout the day. During peak energy consumption times, customers will use water that is already hot. The HPWH's electricity usage is reduced during this peak consumption period, which leads to a decrease in the amount of energy drawn from the grid.

The key research items to be examined in this project are:

- 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.

- Provide a 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.

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 is being installed in SCE's Irwindale Energy Education Center (EEC) and funded by the EM&T program and 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. While the EM&T program is funding the project directly and through a supplemental 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 study, but no other direct cost-sharing or co-funding with any other parties was enabled.

This project will coordinate its research findings with SCE's research partner EPRI and will also inform 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 2021.

Results/Status

Major construction aspects of the laboratory have been completed while still working in accordance with SCE COVID-19 safety protocols to achieve commissioning of the HPWH Test Lab systems. The SCE project team is finalizing and testing telemetry points for the data acquisition system.

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

SCE is working in collaboration with the field study to deploy HPWHs equipped with communication technology that will allow the water heater to be used as a grid-responsive heating technology for the San Joaquin Valley Disadvantaged Communities (SJV-DAC) pilot. This study will only be conducted in twelve residential single-family dwellings of customers participating in the SJV pilots. SCE plans to minimize the risk of any failures of the technology that might occur at the customers' homes by thoroughly testing the communications in the HPWH Test Lab using a variety of cyber-secure transport mechanisms and software schema designed for rural areas. Currently the deployment of the SJV HPWH pilot (as well as the work at the HPWH lab) has been delayed by the ongoing COVID-19 field travel and customer access restrictions at the EEC, but remote programming work is still ongoing and safe-site visits at the EEC are conducted in accordance with SCE Visitor and Employee protocols.

Next Steps

The next important step will be to complete the system(s) commissioning of the HPWH Test Lab to properly assess the operational capabilities of the entire installed system in terms of electrical and hydraulic functionality. Staff training will then commence on the operations of the lab and initiate preliminary testing of acquired HPWH products. The project team will develop video display content on the real-time operations of the SCADA system and the individual products in test bays. The HPWH controls and the grid-responsive communications technology will first be functionally tested in the HPWH laboratory environment prior to deployment in the SJV-DAC test homes. Once installation and testing are complete, the lab may serve as a platform for continued assessment and demonstrations of HPWHs through 2022 and beyond (depending on funding).

3. Projects Initiated Q3 – Q4 2020

DR20.03 Demand Response Technology Enhancements

Overview

Demand response (DR) programs are important resources for keeping the electricity grid reliable and efficient, deferring increased generation capacity, reducing spikes and high loads to transmission and distribution systems; plus 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.

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 to 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.

This objective is approached by evaluating the following:

- 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 in order to be eligible for incentives from SCE and other California Public Utilities, the majority of the future DR resources need to be automated through ADR in order to allow them to be dispatchable and flexible.

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. 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.

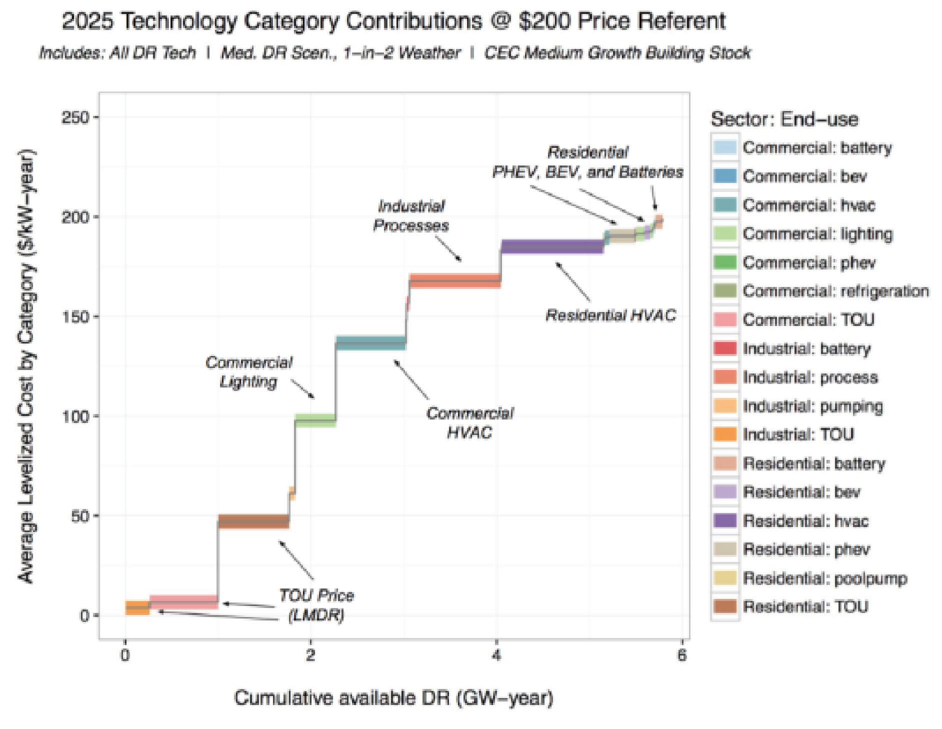


Figure 4: The 2025 technology category contributions below the $200/kW-year price referent. The average levelized costs for each technology category (y-axis) and their contributions to cumulative DR (GW-yr) are shown for the medium DR scenario, 1:2 weather year for all DR technologies.

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 implored 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 be 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 to 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 objectives that include examining the technical capabilities of the portfolio of existing ADR and EM&T projects plus evaluating opportunities for new pilot and program concepts. The LBNL team would then work with the SCE team in organizing these ideas into a set of recommendations based in 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 OpenADR communications messaging to end-uses that are 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 OpenADR messaging structure to provide effective messaging in either an embedded price structure at the customer device, or a day ahead hourly price model that can be transmitted machine to machine.

Task 2. Data Models and Data Communication Architectures

This task 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-use 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 application layer protocols that they carry. Existing technology capabilities and characteristics will be described. The review of tariff communication from the utility grid to customer sites will consider current protocols which include OpenADR 2.0 versions a and b, and will compare these with what is available in IEEE 2030.5 (SEP) using comparative studies already available through organizations such as the OpenADR Alliance. The task will also identify gaps in existing data model functionality that might require further investigation.

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

Task 5. Develop Final Report and Recommendations

LBNL 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 of the project technical memorandums and a summary from 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 works to enable customer participation in SCE's DR programs by providing input to the Codes and Standards (C&S) program, which draws on research into customer preferences and the market potential for DR in California's new construction markets. In addition, to further enable and expand DR in California, SCE is involved in ongoing collaborations 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 enabled.

Results/Status

The data gathering phase of the project was initiated in December 2020 by LBNL researchers in accordance with the scope of work and has progressed as scheduled. Review of the key technology parameters are being collected, including each type of DR tariff and program, storage system performance data, measurement and verification analysis, and customer persistence issues that are being evaluated under the different tasks. Technical factor reviews are underway for OpenADR protocols for 2.0a versus 2.0b, and meetings with the review team have been held via webinar.

Next Steps

This research study will develop 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, building upon the research in the former task. Task one is in progress to collect and evaluate recent ADR program and pilot projects, and related work at other IOUs. Interim reports will be delivered as the work progresses, with additional technical review meetings via webinar in Q1 and Q2 2021.

4. Budget

The following table represents the total expenditures for SCE's 2018-2022 EM&T authorized budget as of December 31, 2020. 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 I2, SCE Demand Response Programs and Activities Expenditures and Funding, January 2021.

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, which may have been scoped and contracted, but not yet executed or monies that have not been spent.

Southern California Edison's Emerging Markets and Technology Program (D.17-12-003)	
Approved 2018-2022 Budget	$14,610,000
Budget Spent to date	$10,777,216
2018-2022 Budget Remaining	$ 3,832,784