CALIFORNIA ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Transactive Incentive Signals to Manage Energy Consumption

December 2021 | CEC-500-2021-060

PREPARED BY:

Primary Authors:
Girish Ghatikar
Alekhya Vaddiraj

Electric Power Research Institute
3420 Hillview Ave
Palo Alto, CA 94304
650-855-8749
http://www.epri.com

Contract Number: EPC-15-045

PREPARED FOR:
California Energy Commission

David Hungerford
Project Manager

Virginia Lew
Office Manager
ENERGY EFFICIENCY RESEARCH OFFICE

Jonah Steinbuck, Ph.D.
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

The authors acknowledge and thank the California Energy Commission (CEC) for funding this research and development project. The authors thank David Hungerford and Matthew Fung of the CEC for their technical guidance, program management, and leadership. The authors acknowledge the technical support by Walt Johnson, a former Electric Power Research Institute employee, during the study's early stage, and Ben Dupont of Nebland Software LLC for maintaining the Transactive Incentive Signals to Manage Energy Consumption system during the study duration.

The authors acknowledge the technical advisory committee and board members (listed in Appendix B) for guidance and feedback. The authors recognize the individual contributions from the California grid operators: the California Independent System Operator, Pacific Gas and Electric Company, Southern California Edison, and the Sacramento Municipal Utility District. The authors acknowledge EPRI employees Ammi Amarnath, Ben Ealey, Ashley Eldredge, Felicia Patten, Cynthia Toth, Felicia Vargas, and Matt Wakefield for their continued support.

Finally, the authors acknowledge the GFO-15-311 project lead organizations (listed in Appendix A) and attendees of the demand response symposium for EPIC GFO-15-311 (listed in Appendix C).

PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Transactive Incentive Signals to Manage Energy Consumption is the final report for the Transactive Incentive Signals to Manage Electricity Consumption for Demand Response project (Contract Number: EPC-15-045) conducted by the Electric Power Research Institute. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at ERDD@energy.ca.gov.

ABSTRACT

In California, the transition from centralized to distributed energy generation and the high amount of variable renewable energy generation are key drivers for the dynamic management of the future electric grid. Without expanded balancing of demand provided by strategies such as demand response resources that respond to real-time system needs, the systemwide integration of variable renewable energy could further increase system costs. Accessing the system- and market-based economic signals on the electric grid enables stakeholders to leverage flexibility from distributed energy resources and market systems and support efficient grid operations to assist transactive load management.

This project proposed a transactive incentive signal to manage energy consumption (TIME) system design that combines real-time system information with load forecasts and distributed generation production. The TIME system calculates and communicates an economic incentive, or price signal, for distributed energy resources that reflects electric system needs. The study developed and put into operation the TIME system in California's wholesale and retail demand response markets. The project team also identified research recommendations and opportunities to move California's demand and grid flexibility vision forward. Early evidence suggests that demand for automation technologies is triggered when customers are provided a reasonable value proposition for demand response. A transactive load management strategy can play a crucial role in economically motivating customers to engage their demand-side resources to enable more efficient integration of variable renewable generation, improve electricity reliability, and potentially value technology applications. Practical applications must develop integrated grid models and value assessments that include grid operators and customers.

Keywords: Transactive systems, transactive load management, demand response markets, distributed energy resources, communication technologies

Please use the following citation for this report:

Ghatikar, Girish, and Alekhya, Vaddiraj. 2021. *Transactive Incentive Signals to Manage Energy Consumption*. California Energy Commission. Publication Number: CEC-500-2021-060.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

Introduction

California's electric grid is undergoing a massive transformation from centralized to distributed generation (on-site generation or decentralize generation) combined with high amounts of variable renewable generation such as solar photovoltaic and wind. This transition will lead to extreme unevenness in where and when gigawatts (GW) of electricity can be over- or under-generated. Without strategies such as demand response (DR) resources that can balance and respond to actual (real-time) system needs, integrating variable renewable energy throughout the grid can further increase system costs. Curtailing renewable energy, maintaining system reliability and stable power-quality, managing baseload generation or resource adequacy, and so on, can add to grid management costs. Accessing the electric grid's system- and market-based economic signals enables customers to leverage flexibility from distributed energy resources and market systems, and support efficient grid operations.

Strategic California's policies related to the project or study are the Global Warming Solutions Act (Assembly Bill 32, Nuñez, Chapter 488, Statutes of 2006) and Renewables Portfolio Standard (Senate Bill X1-2, Simitian, Chapter 1, Statutes of 2011). Attaining these policy goals require engaging customer-side resources and market-based programs to address the generation unpredictability posed by the renewables — a focus the state of California is pursuing.

Transactive energy is used to actively manage energy generation and consumption through the use of energy market or grid signals. A transactive (energy) load management system combines actual system information with forecasts of loads (demand) and distributed generation to derive an economic incentive or price (transactive load management) signal that reflects electric system needs and market conditions. The project team designed, developed, and operated a prototype system to manage energy consumption (TIME [transactive incentive manage energy]) and understand better how transactive load management pricing signals could benefit DR programs and customers.

Project Purpose

This project developed, tested, and used a transactive signal that utility customers can use to automate their load management strategies and addressed several central questions about transactive load management, including:

1. What should the signal design be?
2. What elements should the signal be composed of, and in what proportion?
3. How do variations in the signal composition affect consumer behavior?
4. How can the design and operation of the signals and systems integrate supply- and demand-side markets in California?

Project Approach

The project was conducted in two phases. The first phase developed a framework comprised of a transactive load management signal design and a transactive load management price structure to represent California's wholesale (supply-side) and retail (demand-side) electricity markets. The second phase — the main focus of this report — described the findings and recommended next steps following the development and operation of the prototype TIME system.

The project team reviewed the existing electricity markets, regulatory structures, and grid operations in California and conducted a literature review. In this process, the researchers analyzed eight independent field-demonstration projects, consulted technical advisors, and developed a transactive load management signal for price communications.

The key stakeholders remained engaged at both phases of the study for technology and knowledge transfer activities. The project team discussed the research results with members of a technical advisory committee and technical advisory board to improve the research outcomes. The resulting review and feedback from the committee and board members and other stakeholders enhanced the study's findings and recommendations.

Project Results

the proxy price signal was used by research teams of several independently operated and managed projects funded through Electric Program Investment Charge (EPIC) solicitation GFO-15-311. The researchers made recommendations in applied research and development, field demonstrations, and market applications including key recommendations for future research to support California's policy objectives.

The project results are in three categories:

1. *System design, development, and operations*: A key outcome is a TIME system design that considers California-centric challenges including how to (a) address the generation variability posed by renewable resources such as solar and wind; (b) account for social costs in the form of greenhouse gas or carbon emissions, as the wholesale market price or energy cost determinants; and (c) include demand variability as an additional determinant of the retail market price or cost.
2. *Implementation by DR Resources*: The results from the residential, industrial and agricultural customers that participated in the demand- and supply- side projects show that the 24-hourly day-ahead California wholesale market prices constitute a consensus base case to determine the transactive load management prices.
3. *Integrated transactive load management signals for DR Resources*: The study concluded that the transactive load management price design must include various grid and customer data inputs for forecasting and real-time analytics of supply-side (wholesale) and demand-side (retail) markets, generation sources generation, and demand variability.

The study results provide positive information that can advance research focusing on transactive load management and engaging DR resources for grid balancing applications. Simultaneously, integrating integrated grid models and value assessment that includes grid operators and customers is critical for practical applications.

Technology/Knowledge Transfer/Market Adoption (Advancing the Research to Market)

The study conducted technology and knowledge transfer to publicize findings, solicit feedback from industry leaders and improve the results and recommendations. The researchers leveraged information from the technical advisory committee and technical advisory board members and feedback from industry experts to improve results, technology, and knowledge transfer. The committee and board included more than 25 qualified technical, business, and regulatory experts in electricity markets, DR, and transactive systems research. The study hosted a DR symposium that brought all study participants, including more than 50 stakeholders, to review the study. The project team presented preliminary findings of the study in relevant national forums such as the U.S. Department of Energy and GridWise Architecture Council's Transactive Energy Systems Conference and Workshop and the DistribuTECH International Conference as well as to the California Energy Commission staff and commissioners.

The design and use of the TIME system prototype successfully demonstrated the early-stage use by the industry and the customer technologies. While past California programs had success with DR and dynamic pricing, the study has shown that diverse distributed energy resource technologies, scalable system architecture, and vendor technologies can be operated using real-time wholesale and retail electricity signals.

Benefits to California

The study provided the following benefits to California and its ratepayers.

1. The TIME system can address a critical need to prioritize the economic value and integrate California's supply- and demand-side electricity markets. This motivation and integration can unlock the full value from a customer's DR resources to enable efficient integration of variable renewable generation and improve electricity reliability.
2. The transactive load management price signals can enable DR participation for supply- and demand-side markets under California's aggressive renewable generation goals. Standardized approaches can value the technology enablement costs and enable customer-chosen DR resources to integrate with utility systems and participate in DR markets.
3. Evidence from the independent projects suggests that demand for automation technologies is triggered when customers are provided a reasonable value proposition for DR participation. This project has demonstrated that it is possible to create that value proposition by designing and delivering hourly or sub-hourly prices designed to reflect real-time grid and market conditions to customer systems and devices — and that those customers can, and will, respond.

CHAPTER 1: Introduction

For electricity consumers, grid operators, and businesses to significantly benefit from the modern electric grid, it must be inextricably linked with technological and regulatory advancements. California’s electricity supply is undergoing a massive transformation from centralized generation to distributed generation combined with a high penetration of variable renewable generation. This transition will lead to extreme locational and time variability where and when gigawatts (GW) of electricity will be over- or under-generated. An earlier analysis by the California Independent System Operator (California ISO) shows early morning and late evening variability in the range of 7 GW–14 GW, respectively (California ISO 2013). Without expanded balancing provided by strategies such as demand response (DR) resources responding to actual (real-time) system needs, the systemwide integration of variable renewable energy can further increase costs. Renewable curtailment, maintaining system reliability and stable power-quality, managing baseload generation or resource adequacy, and so on, can add to higher electricity prices (Greenstone 2019). However, accessing the grid’s system- and market-based economics enables stakeholders to leverage flexibility from distributed energy resources and market systems and supports efficient grid operations using transactive load management (TLM). Here, TLM is defined as a method to leverage end-user flexibility through DR services and the use of advanced energy technologies and economic incentives, such as real-time electricity prices, to motivate and facilitate customer response.

Supporting the California Energy Commission’s (CEC) vision, the project team designed and developed a prototype system that combines real-time system information with load (demand) and distributed generation (DG) forecasts. The resulting economic or price “signal” reflected the electric system needs (CEC 2015). The research developed a transactive incentive signals to manage energy consumption (TIME) system based on the principles of an integrated grid and the electricity market context in California. The development included the participation of engaged electric grid stakeholders who provided feedback on the findings and recommendations. The resulting interfaces between the TIME system and customer response through TLM will better support grid stability and reliability that fairly considers customers’ flexibility and electric grid requirements through pricing models.

Project Purpose and Background

The purpose of this study was to develop, test, and make operational a transactive signal that utility customers can use to automate their load management strategies (CEC 2015).

This research report describes the findings from TLM signals' development and operations within the TIME system to express the grid conditions as a proxy price for resources (both supply- and demand-side). The findings are drawn from the TIME system's operationalization through field deployments of several independently operated and managed projects (independent projects). The research recommendations relate to applied research and development, field demonstrations, and early-stage markets. Finally, the report makes key recommendations for future research in support of California’s policy objectives.

This report's findings and recommendations leverage an earlier deliverable (Phase 1) that described the supporting California policy objectives, design, and architecture of the TLM-based system and was published under contract with the CEC (Ghatikar and Johnson 2017). To avoid the repetition of previous research outcomes in this report, Chapter 2 summarizes this supplemental report. The key California policy drivers for the study are the state's Global Warming Solutions Act (Assembly Bill 32, Nuñez, Chapter 488, Statutes of 2006) (LegInfo 2006) and Renewables Portfolio Standard (Senate Bill X1-2, Simitian, Chapter 1, Statutes of 2011) (LegInfo 2011). The AB 32 mandates the greenhouse gas (GHG) emissions reduction goal of returning to 1990 levels by 2020 and a Cap-and-Trade Program. Attaining the policy goals requires customer-side resources and market-based programs to address the generation variability posed by the renewables—a research focus for the state.

As alluded to the CEC's research program under Grant Funding Opportunity (GFO) 15-311, "Advancing Solutions That Allow Customers to Manage Their Energy Demand" (CEC 2015),

"The purpose of the research…will be to develop, test, and operationalize one or more transactive signals that can be used by utility customers – and the other Recipients under this solicitation – as a basis for automating their load management strategies. It is expected that the signal development process will involve collaboration with Group 1 and 2 Recipients."

As expressed in the GFO, a TLM system combines actual system information with forecasts of loads (demand) and distributed generation (DG) to develop an economic incentive or price (TLM) "signal" that reflects system needs. The GFO also required another set of eight independent and related field-deployment demonstration projects to evaluate the TLM signals' efficacy for their customers and technology approaches. These independent projects were managed under independent and direct agreements with the CEC. These independent projects tested the effectiveness of using the TLM signals and have reported the findings from its application within retail-based DR programs (demand-side markets) and wholesale DR market products (supply-side markets). Evaluation of field tests conducted by the independent projects using the TLM signals is outside this study's scope. Summary of these independent projects is listed in Appendix A.

The TIME research identified a transactive system and TLM signal design that considers the electricity system's transition to distributed generation and can address variability from renewable generation through the market and system-based operations. The term *transactive,* in the electricity context, refers to buying and selling of electricity (inherently, using two-way communications) based on (1) economic signals, where a customer's actions are based on cost minimization; (2) engagement where grid operators, energy service providers, and *prosumers* (producers and consumers of energy) participate; and (3) exchange where information exchange happens among all participants. In this application, a transactive system leverages a customer-centric strategy for flexible management of demand-side resources such as end-use loads, energy storage, electric vehicles (EVs), and so forth.

The TLM price signals and the TIME system are key components of a transactive system that ensures customers realize value from flexible energy use. Customer engagement is based on the well-understood premise that any market- and system-based strategy must support customer and grid value streams. For instance, the TLM prices represent such a value, where a customer determines when and how to flexibly manage their energy resources.

The critical questions that the study addressed relative to the TLM include the following:

1. What should the signal design be?
2. What elements should the signal be composed of, and in what proportion?
3. How do variations in the signal's composition affect consumer behavior?
4. How can the design and operation of the signals and systems integrate supply- and demand-side markets in California?

Report Organization

Chapter 2 describes the study's approach that includes an executive summary of earlier Phase 1 research outcomes and focuses on the development and operation of a prototype TIME system for field demonstrations of TLM pricing applications.

Chapter 3 summarizes the study findings from field deployments using standardized TLM signals based on ongoing California's electricity market offerings. It also lists study and ratepayer benefits relative to reliability, cost, and safety.

Chapter 4 lists technology, and knowledge transfer activities, and the stakeholders that were engaged to conduct a sensitivity analysis of the study results and benefits.

Chapter 5 lists conclusions, recommendations, and research opportunities based on research findings, stakeholders' comments, and the sensitivity analysis, using a survey.

The key terms and definitions used in this report are in the Glossary and List of Acronyms at the end of the report.

CHAPTER 2: Project Approach

The study was executed in two phases. Phase 1 focused on developing a framework for the TIME system comprised of TLM signal design and TLM price structure to represent California's wholesale (supply-side) and retail (demand-side) electricity market design. A prototype TIME system developed and operated for the study integrated the TLM signals and TLM prices with California's electricity markets. The following sub-sections summarize these activities. Phase 2, which is this report's focus, was to describe the findings and recommend the next steps based on the development and operationalization of a prototype TIME system described in the section titled Phase 1 Research Summary.

The study engaged stakeholders during both phases for technology and knowledge transfer activities, as listed in Chapter 4. The study established two groups for improvement and thought leadership:

1. Technical advisory committee (TAC): The TAC comprised of leading practitioners and subject matter experts in price-responsive signals grid systems. The TAC included representatives from independent projects and stakeholders from California, and standards organizations were engaged through quarterly meetings.
2. Technical advisory board (TAB): The TAB comprised of national experts from the public sector and California agencies engaged in the technical, business, and regulatory aspects of electricity markets, demand response, and transactive systems. The project team reviewed the strategic milestones through less-frequent semi-annual meetings.

Research results were discussed with TAC and TAB members to improve the research outcomes. The resulting review and feedback from the TAC and TAB members and other stakeholders enhanced the study findings and recommendations.

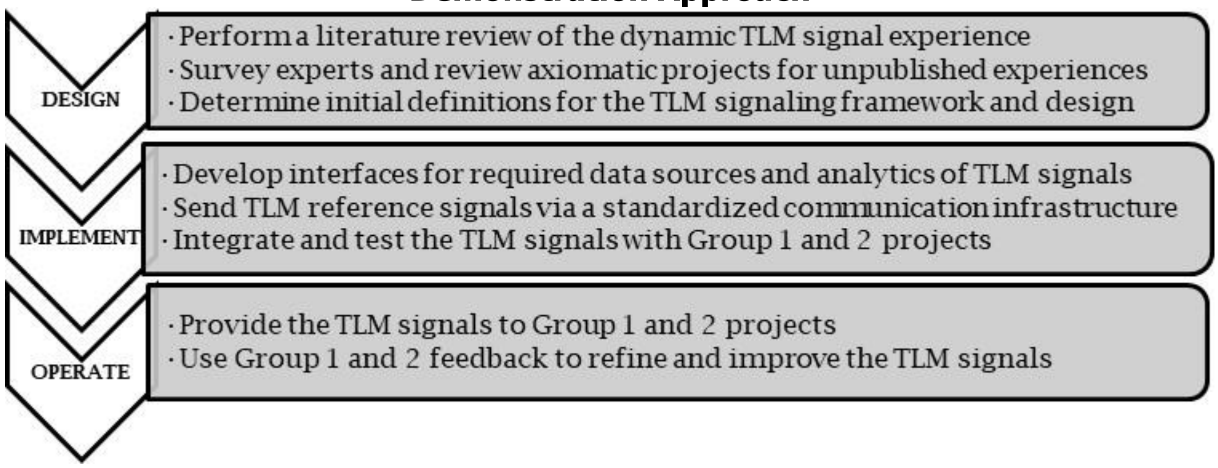
The following sections summarize Phase 1 and additional research that focused on a prototype TIME system's development and operations. The results from the entire study served as a guiding principle for the findings and recommendations.

Phase 1 Research Summary

This section summarizes an earlier published Phase 1 report (Ghatikar and Johnson 2017). This Phase 1 research reviewed California's policy objectives, existing market design, and related independent project requirements focusing on TLM signal design and pricing structure. California Assembly Bill 32 (LegInfo 2006 and California Air Resources Board 2018) and SB X1-2 (LegInfo 2011) are primary drivers for these goals. AB 32 mandates the greenhouse gas (GHG) emissions reduction goal of returning to 1990 levels by 2020 and a Cap-and-Trade Program. SB X1-2 requires retail sellers of electricity and local publicly owned electric utilities (POUs) to increase their procurement of eligible renewable energy resources to 20 percent by the end of 2013, to 25 percent by the end of 2016, and to 33 percent by the end of 2020.

The Phase 1 research focused on developing a TLM system framework and the design and development of a TLM pricing and signal structure. The preliminary findings from Phase 1 research and the next steps were developed through a collaborative approach, as required by the GFO-15-311. The Phase 1 leveraged a collaborative approach for field tests of the TLM system. The framework and design of TLM signals were conducted through design, implementation and operation, as described in Figure 1.

Figure 1: Transactive Load Management Research, Development, and Demonstration Approach



Source: EPRI

Researchers reviewed the existing electricity markets, regulatory structures, and grid operations in California. Further, the researchers analyzed the field deployments of TLM signals with customer's demand-side resources, conducted a literature review, and solicited expert consultation with the TAC and the TAB. The results were used to design the TLM framework and price signals through a prototype TIME system that reflected market and system conditions. This research method is illustrated in Figure 2.

Figure 2: Method for the Design of Transactive Load Management Signals and Prices

Source: EPRI

The research considered California's intended future clean energy system, electricity markets, policy, and regulatory requirements, including consideration of the California Independent System Operator (California ISO) and the distribution utilities' operational structure. The inclusion of the California ISO and the distribution utilities was critical to ensuring that the TLM framework and signal design can have applications within the context of their grid operating models.

California’s Electric Grid and Markets

The project team reviewed the existing regulated market structure, electricity market supply planning and operations, wholesale electricity market pricing system, and DR programs that enable customer load participation through the TLM. California’s clean energy Senate Bill (SB) 350 requires 50 percent of renewable electricity procurement by 2030 ([SB 350] and [LegInfo 2015]). A high share of renewable generation adds locational and time-based variability and intermittency challenges. The inclusion of firm generation resources such as fossil or nuclear generation or large-scale energy storage can address these challenges. However, the addition of fossil-based electricity defeats the policy goal to reduce pollution. Hence, SB 350 suggests a similar share of “grid balancing” and “flexible demand” resources are necessary for grid reliability, stability, and cost-effectiveness. A TLM system design inclusive of existing electric grid infrastructure and markets can support California’s policies.

The consideration of California’s existing electricity markets included a regulated electricity market structure comprised of a wholesale electricity pricing system and retail electricity markets. While the California ISO manages the wholesale electricity pricing, most California energy consumers receive electricity services under tariffs from the three investor-owned utilities (IOUs): Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric Company (SDG&E). The California Public Utilities Commission regulates these IOUs and approves the retail electricity rate tariffs for all customer sectors (commercial, industrial, and residential). While the energy price per kilowatt-hour (kWh) is a significant element of the retail tariffs and constitutes the primary cost for residential customers, the price per kilowatt is another primary cost for large commercial and industrial customers.

Depending on the type of electricity rate tariffs, a customer can use their energy resources to participate in a wholesale or a retail electricity market (or both) through rules set forth by the California ISO and IOUs, respectively. A customer’s participation in wholesale or retail electricity markets is termed “supply-side” or “demand-side” markets, respectively. The architectural design for a TLM signal considers the diversity within customers (residential, commercial, and industrial), energy resources (e.g., loads, energy storage), and market design (wholesale and retail customers).

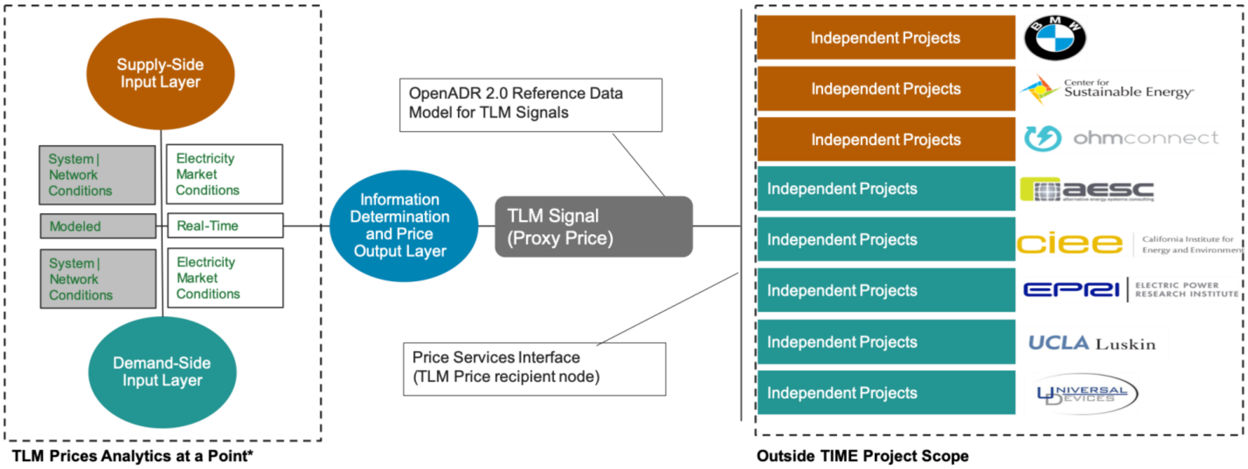
Architecture for Transactive Load Management Price Communications

The architectural framework for the TLM signals communicated by the TIME system was developed to provide a common base-case reference price to diverse benchmark approaches to system design, technology, and customer sectors represented by the independent projects.

Figure 3 shows a resulting architecture for TLM price communications using a TIME system. The architecture comprises of TLM analytics and models necessary to forecast prices and real-time adjustments, communications for the exchange of information among participants; and systems that engage a multitude of grid operators, customers, and distributed energy resources. A prototype TIME system developed on this architecture sent the TLM price signals to the customers, aka GFO-15-311 independent projects.

In the design, the forecasted and real-time price analytics are based on the existing system and market conditions for supply- and demand-side markets, including the GHG considerations of the generation sources, as inputs at a reference “point” (represented by the dotted rectangle on the left in Figure 3). The reference point is a generic construct within the grid to account for locational granularity. For example, the California ISO wholesale electricity price points or nodes. The information from the existing market and system conditions can be used to determine the TLM price. The TLM price was communicated to the independent projects using a price service interface (PSI) using OpenADR 2.0 (OpenADR Alliance 2013). It should be emphasized that the design of the TLM system and prices is independent of any standard. The TLM signals could be communicated by an existing standard or by developing a new standard.

Figure 3: Design Framework for Transactive System, Prices, and Communication Interfaces



Note: The TLM price analytics "point" can be a generic construct within the electric grid based on the future advanced TLM system design that may account for spatial granularity.

Source: EPRI

To ensure that a diversity of vendor technologies and customer DERs can receive TLM prices and respond efficiently, standardized communications that enable interoperability across the utility and customer systems were supported. California's wholesale electricity pricing market structure was used to propose a TLM system's analytical framework to calculate the TLM prices and disseminate them through TLM signals that used a standardized communication platform.

Transactive Load Management Signaling System Design

California's day-ahead and real-time electricity price indicators represent the transmission system's state (wholesale energy markets). The California ISO operates California's day-ahead and real-time (intraday) wholesale energy markets. The locational value of supply-side resources is calculated as a price at thousands of pricing nodes (Pnodes) around the state. These prices are used in the settlement of generation and supply-side DR resources. The California ISO locational marginal prices (LMP) at the Pnodes determine the wholesale market electricity prices (CAISO 2019a).[1] On the other hand, loads (including demand-participating DR

[1] A Pnode is "A single network Node or subset of network Nodes where a physical injection or withdrawal is modeled and for which a Locational Marginal Price is calculated and used for financial settlements." (Source: California ISO). Pnodes are created (if needed) in response to new interconnection requests. An LMP is "The

loads) are settled at much less granular load aggregation points (LAPs) that are usually the average of the locational prices within California's service territories IOUs.

The customers participating in the California ISO markets are exposed to two price structures: (1) a wholesale price that is based on the LMPs across the grid (the customer's participation in the supply-side markets use this price for compensation); and (2) a retail price based on an aggregation of Pnodes into large aggregations or LAPs used by the customer's energy resources that participate in demand-side markets. Both these constructs are critical components of the electricity markets managed by the California ISO. The specific mappings of Pnodes into aggregations for LAPs (and Sub-LAPs),[2] as defined by the California ISO, are available on the California ISO website (CAISO 2019b). More information on the California wholesale energy markets is available on the California ISO website (CAISO 2019c). Depending on the nature of the independent project receiving the TLM prices, one or the other of these supply- or demand-side prices may be used to derive a TLM signal.

The TIME system prototype was developed to estimate non-existent distribution electricity market prices. In this prototype, a distribution service provider (e.g., IOU or community choice aggregators) and supply-demand variation adjustments (distribution system price adjustment) were used as a proxy to communicate retail electricity prices and to reflect distribution and transmission system conditions.[3] In practice, these price adjustments should consider utility-specific needs and existing market and tariff requirements, including the electricity system and market conditions and GHG components. The resulting integrated and inclusive market-based prices are called *integrated TLM prices.*

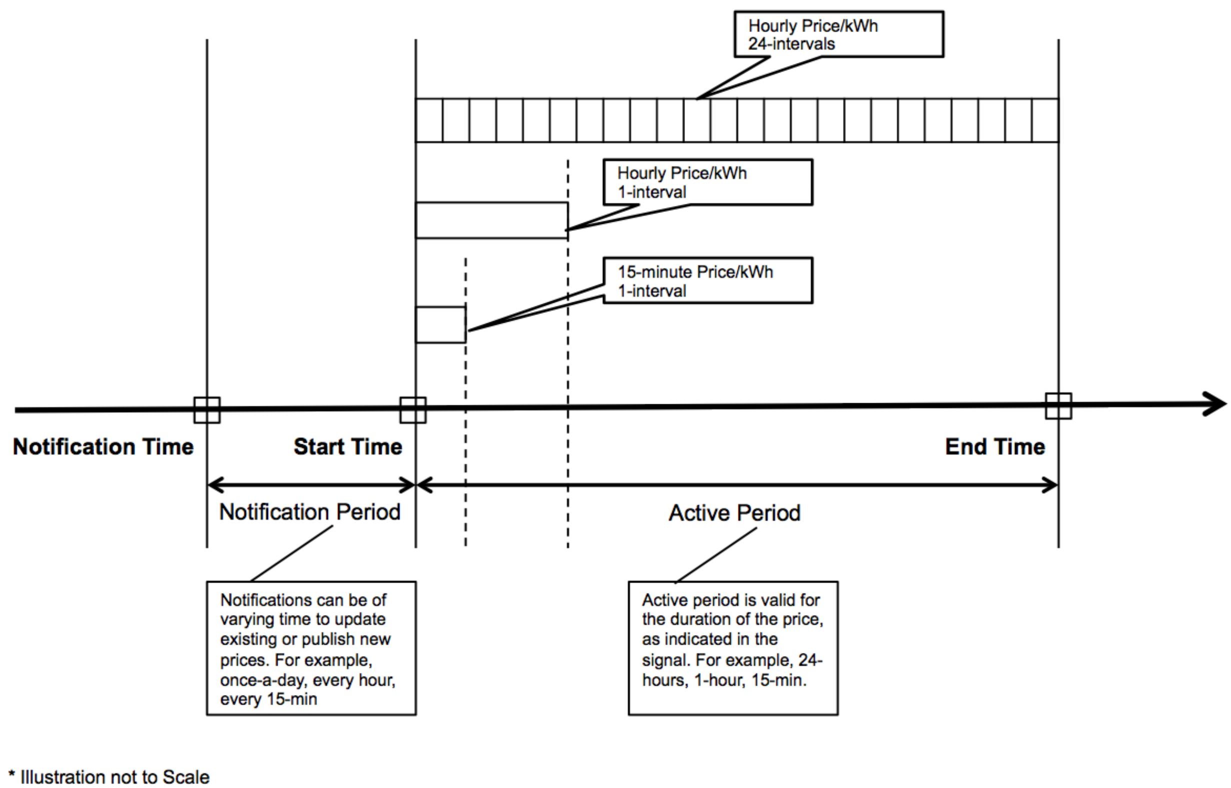
A TIME system prototype and a generic price signal design were developed to communicate TLM prices to the GFO-15-311 independent projects and constituted either the wholesale or proxy retail price. The independent projects could adjust the price signal to reflect the energy value more closely at a specific location. However, the final integrated TLM price was required to consider the distribution and GHG components to meet California's clean electricity system goals and current utility electricity pricing structure and business models. This generic signal design is associated with one or many price proxy nodes within California's transmission and distribution system that the TLM signal is used to communicate. The generic TLM signal design maps an existing California ISO wholesale DR market price notification framework and IOU DR programs, as shown in Figure 4.

marginal cost ($/MWh [megawatt-hour]) of serving the next increment of demand at that Pnode consistent with existing transmission constraints and the performance characteristics of resources.

[2] An LAP usually is the average of the LMPs within the service territories of the California investor-owned utilities. Sub-LAPs are "Areas within default LAPs that group buses with similar grid impacts" (CAISO 2019b, 2019c).

[3] These are proxy prices used to motivate responses; they do not necessarily represent the prices users pay as determined by their retail electricity rate tariffs.

Figure 4: Construct for the Design of Generic Transactive Load Management Signal(s)



Source: EPRI

This generic signal design includes the wholesale electricity market prices and the retail DR program design constructs that communicate the prices (as for a peak-day pricing program). The TLM signaling system design is agnostic to one specific communication standard or data representation. The project team created a reference design using OpenADR 2.0 because it was designed to communicate an hourly price and has a large base of existing users in the industry. The TIME system was designed for each group 1 and group 2 independent projects to receive one or many TLM signals, including different electric service provider variations. Group 1 and group 2 independent projects focused on participation in the demand- and supply-side markets. Each of these TLM signals is distinguished in the utility or the IOU DR market contexts, as:

[ProgramTariff | MarketContext] . [Pnode | APnode, DistributionUtilityTerritory]

In this signaling format supported by OpenADR 2.0, ProgramTariff, and MarketContext, a specific program is designed by the electric utility to disseminate the TLM prices to the DR resources. Such a format already exists in California’s DR programs offered by the IOUs. Pnode (which relates to wholesale electricity market price), APnode (which relates to aggregated price node used by the electric utilities), and DistributionUtilityTerritory refer to distribution system price adjustments to reflect the retail cost of energy to the consumers.

The TLM signal design with a current wholesale electricity market price covers the supply-side DR prices. A demand-side DR program may want to use the LAP (or Sub-LAP) prices as a starting point to represent the distribution prices. As a result, the TIME system was designed to formulate a TLM price with a simple distribution system adjustment to either the Pnode or

APnode that reflects the demand-side program. This system was developed to understand that a more comprehensive distribution system adjustment price may require a significant market and technology data and analyses. However, such analysis was outside the study's scope. The TIME system developed uses a simple representation of distribution system price and extant wholesale system prices—forming demand- and supply-side prices.

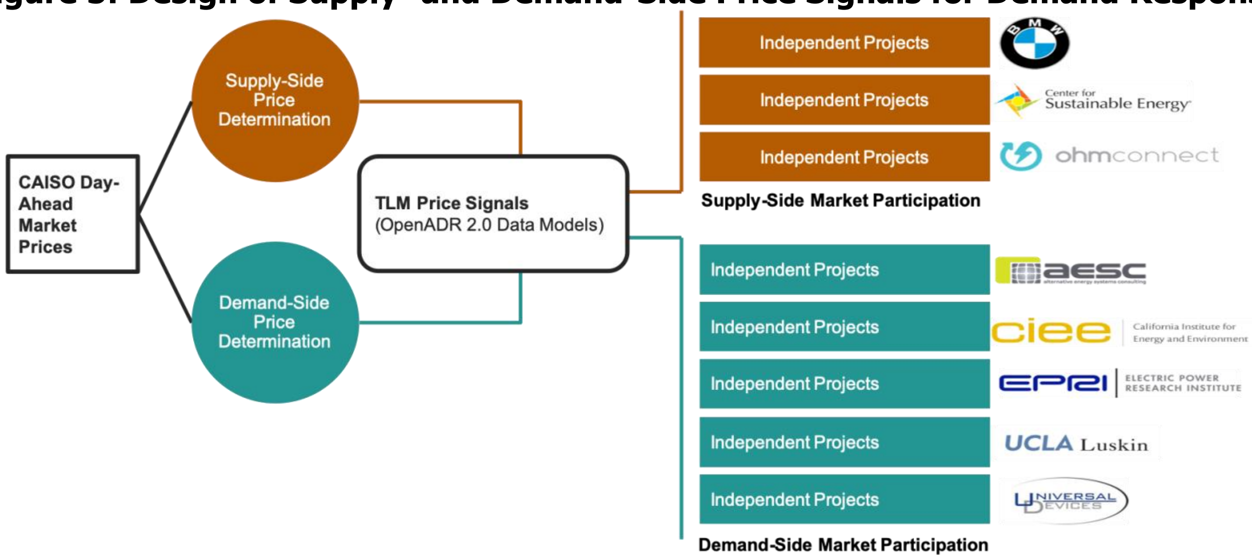
Once the TLM system architecture and TLM signal design were determined, the research team next developed and operated a prototype TIME system to disseminate TLM prices to GFO-15-311 independent projects – a key focus of this report.

System Development

A prototype TIME system was developed to support the following key objectives, as illustrated by Figure 5.

1. Integrate the TIME system with the California ISO day-ahead and real-time wholesale electricity pricing system. The integration enabled the TIME system to obtain the California ISO market prices to form the TLM prices for supply-side markets (supply-side price determination).
2. Develop a distribution system pricing and analytics design in the TIME system for demand-side markets (demand-side price determination).
3. Deploy a prototype TIME system for TLM price signals and standardized communications to interface with customer's DR resources through GFO-15-311 group 1 and 2 independent projects.

Figure 5: Design of Supply- and Demand-Side Price Signals for Demand Response



Source: EPRI

The California ISO wholesale electricity market prices formed the basis for the TLM prices. The California ISO publishes the LMPs for the wholesale electricity market through Open Access Same-Time Information System (OASIS) (CAISO 2019d). One of the pertinent pieces of information from OASIS is the real-time data related to the wholesale electricity market prices. The integration of the TIME system and OASIS provided access to thousands of Pnode LMPs. Although OASIS publishes LMPs for many market types (e.g., day-ahead, intra-day), the team conducted surveys of the independent project participants to determine the specific type to use.

The day-ahead hourly prices were a common baseline for all the independent projects. It should be noted that select independent projects supported intra-day or sub-hourly prices. Since the study required communication of the same TLM prices across each supply- and demand-side participant, access to LMPs other than the day-ahead hourly prices were outside the scope. The design of the TIME system, however, is scalable to support additional price signals.

For supply-side market participation, the research team concluded that the Pnode LMPs published by the California ISO were the lowest desired spatial disaggregation points. As a result, the day-ahead hourly LMPs were used as the determinant of TLM prices for the independent projects for supply-side market participation by the DR resources. The study assumed that the transactive nature of TLM prices was inherent in the California ISO's calculation of the LMPs.

For the demand-side market participation, the assessment was not straightforward, as the decoupling of the retail electricity prices from the wholesale electricity prices is not a trivial task. For example, the demand-side markets are not subjected to intra-day and intra-hour (real-time) volatility as seen in the supply-side markets. As a result, the customer electricity rate tariffs are designed for longer-term revenue recovery and not real-time market volatility. The APnode prices for the IOU LAPs showed the lowest spatial disaggregation for wholesale electricity market prices to support transactive-based TLM prices. As a result, the TIME system accessed the APnode price for each of the three IOUs and their respective load aggregation points. These APnode prices were adjusted to distribution-centric prices by a constant multiplier. To determine a constant multiplier during the TIME system development, the 2016 California average annual retail electricity price per kWh of $0.15 for all customer sectors was used (EIA 2017). At the time of this report publication, the 2019 California average annual retail electricity price for all customer sectors was $0.17 per kWh (EIA 2020). In addition to understanding that retail electricity price is what a typical residential customer would pay for energy, the rationale to calculate dynamic average retail electricity prices was to: (1) recognize the higher differential with the wholesale electricity prices, (2) determine the multiplier for the retail electricity prices that represent transactive TLM prices in direct relation to the wholesale electricity prices, and (3) show the economic value from flexible management of customer's DR resources.

This price multiplier (m) was determined by selecting a common price (p) from one of the APnodes during an off-peak time and application of a simple formula, as follows:

p * m = $0.13 per kWh. Hence *m = $0.13 per kWh/APNode price*.

The multiplier (m) value was determined to be 0.0036 for an APnode price of $35 per MWh (or $0.035 per kWh). This multiplier is an indicator of the distribution price being greater by 3.6 times the wholesale price at the APnodes (in kWh). It means the distribution price calculated by the TIME system could track the day-ahead or real-time APnode price changes.

This multiplier value was applied to the respective IOUs' day-ahead hourly APnode prices and published to each of the demand-side independent projects. These published prices were communicated, as proxy prices, through OpenADR 2.0 standardized data format.

During the development, the project team recognized that the multiplier for the distribution system price adjustment was a simplified representation of the retail electricity prices. More advanced methods are necessary to ensure that the prices accurately represent the real-time electric system and market conditions at different spatial and temporal levels.

Once the prototype TIME system was developed to support supply- and demand-side markets, the TLM prices were published in a standard OpenADR 2.0 data format. The next crucial step was to provide operational support of the TLM system and integrate TLM signals with the GFO-15-311 independent projects.

System Operations

The TIME system prototype inherited existing work in developing an OpenADR 2.0-based client-server system architecture to communicate DR signals to end-use devices and systems. With the extension of the OpenADR 2.0 server system to support TLM prices, the independent projects either leveraged the existing OpenADR 2.0 client system or developed one to integrate with the TIME system to receive the TLM price signals. While the GFO-15-311 required all independent projects to integrate with the TIME system, as noted in Table 1 (that shows how the lead organizations applied the TLM signals), only five of the eight independent projects used the TLM prices to optimize the management of DR resources.

Table 1: Summary of GFO-15-311 Project's Application of Transactive Load Management Signals

Lead Organization	Application of TLM Signals
BMW North America (NA)	Participated in the supply-side markets to receive day-ahead real-time wholesale market prices from the TIME system.
Center for Sustainable Energy (CSE)	This project did not utilize the TLM signals.
OhmConnect	Participated in the supply-side markets to receive day-ahead real-time wholesale market prices from the TIME system.
Alternative Energy Systems Consulting (AESC)	Participated in the supply-side markets to receive day-ahead real-time wholesale market prices from the TIME system.
California Institute of Energy and Environment (CIEE)	This project did not utilize the TLM signals.
Electric Power Research Institute (EPRI)	Participated in the supply-side markets to receive day-ahead real-time wholesale market prices from the TIME system.
University of California Los Angeles (UCLA) Luskin Center	This project did not utilize the TLM signals.
Universal Devices	Participated in the supply-side markets to receive day-ahead real-time wholesale market prices from the TIME system.

Source: EPRI

To ease the integration with the TIME system, the project team provided standard instructions to each of the GFO-15-311 independent projects to connect their end-user devices or systems. This integration included the following steps:

1. Develop an OpenADR 2.0 compliant client system that is capable of securely receiving the TLM prices.
2. Obtain and install OpenADR 2.0 security test certificates for the client system.
3. Create and configure the secure OpenADR 2.0 client system on the TIME system.
4. Connect the OpenADR 2.0 client system to communicate with the TIME system.

Additionally, the instructions provided details on the TLM signals structure and how an OpenADR 2.0 client system can subscribe to the Pnode prices.

Transactive Load Management Signal Structure

The TLM signal was dispatched in a standard OpenADR 2.0 signal payload as a DR event. OpenADR 2.0 supports two profiles for a client system: 2.0a and 2.0b profiles, depending on the complexity of a DR program and market requirements (OpenADR 2013). The 2.0a profile is a simple profile with limited features intended for basic DR programs and end-use devices or systems with limited computing capabilities. For example, the 2.0a profile would send operation modes 0, 1, 2, and 3, indicating the severity of supply-side conditions to the DR resources. The 2.0b profile is advanced, with many features and services. For example, the 2.0b profile could include grid requirements such as prices and power or energy changes and include telemetry services required for wholesale DR markets (Ghatikar 2010, 2012; EPRI 2020). The TLM signal was published using a 2.0b profile to communicate dynamic TLM prices. The following structure was used from the OpenADR 2.0b profile data models.

- Service: EiEvent
- Signal Name: ELECTRICITY_PRICE
- Signal Elements: marketContext, and eiTarget

A single TLM pricing event was created for each day, using these OpenADR 2.0 data model constructs. Each TLM pricing signal contained 24 price intervals for each hour of the operating day (expressed as a *pseudo price* or *proxy price*). Separate TLM pricing events were provided for each California IOU territory (based on the California ISO APnode prices for each IOU’s Load Aggregation Point) and for selected Pnodes (the California ISO LMPs).

Subscriptions to Transactive Load Management Prices

For each Pnode, a matching group name and DR program or MarketContext were established on the OpenADR 2.0 server system. These group names were simply the names for the APnodes or Pnodes provided by the California ISO OASIS. The DR event of TLM prices from the TIME system has a MarketContext string that matched the group name (and the California ISO node name).

The OpenADR 2.0 client system for each of the GFO-15-311 independent projects received DR events for the groups they belong to, as recorded on the TIME system. Each OpenADR 2.0 client system was assigned to at least one group. It means that each of the GFO-15-311 independent projects were assigned a group (single client) or more than one group (multiple clients). Instructions for requesting the addition of a new OpenADR 2.0 client in the TIME system to more than one group followed the standard instructions.

Each of the independent project participants developed their OpenADR 2.0 compliant client system independently. While some client systems had completed the certification process for compliance with the OpenADR Alliance (OpenADR Alliance 2019), others required additional support that the project team did not anticipate. The individual TIME system integration with independent projects required a higher degree of technical support that was not anticipated in the study's scope. Examples include providing information on the OpenADR 2.0 client system development, education on the difference between the California IOU signals for commercial DR programs versus the TLM price signals, and technical assistance to integrate the client system with the TIME system for independent projects. Overall, the degree of technical support could have been higher if a standards-based approach was not taken to publish the TLM. The interoperability was seamless for some independent projects whose OpenADR 2.0b clients were certified by the OpenADR Alliance.

CHAPTER 3: Project Results

This chapter summarizes the results, benefits, opportunities, and knowledge transfer activities identified by the project team. Each of the independent projects was required to integrate with the TIME system to receive TLM prices. Mandating all the independent projects to integrate with the TIME system was outside the scope of the study. A group of independent projects that used TLM prices was shown earlier in Table 1 in Chapter 2.

Additionally, the chapter summarizes the study's benefits and opportunities for California. A survey conducted at the DR Symposium for EPIC GFO-15-311, held at the EPRI offices in Palo Alto on July 22, 2019 (DR Symposium), focused on the benefits of the TIME and TLM vision as it applies to California. While the emphasis was on California electricity markets, some study findings could be relevant to other regions.

The study results are categorized in the following three core areas. While most of the results were based on the project team's research analysis, the results were reviewed by the TAC, TAB members, and the DR Symposium attendees. The TAC and TAB members regularly engaged in the study's technology and knowledge transfer to review and provide feedback. The DR Symposium attendees' review focused on the operations and applications of the TIME system.

1. TIME System Design, Development, and Operations: This activity was comprised of the design and development of the TLM framework, TLM signals, TIME system prototype, and the operations of the prototype TIME system.
2. Implementation by Demand Response Resources: This activity included feedback of TLM signal applications and implementations by independent projects, which were composed of the supply- and demand-side market participation and use of respective TLM signals.
3. Integrated TLM signals for DR Resources: This activity included reviewing field applications of TLM signals for a diversity of DR resources and supply- and demand-side markets to elucidate the results relative to the goals and objectives of GFO-15-311.

System Design, Development, and Operations

Analysis of California's existing regulated electricity market structure, literature reviews, independent project reviews, and feedback from the TAC and TAB formed the platform for recommendations of critical metrics that constituted the TLM system, price(s), and signal(s).

The overarching system design was based on a generic TLM signal and TLM price models that described the ideal state. The state included considering California's electricity market operations and developing TLM signals that consider a diversity of DER and market operation models to interoperate with a diversity of vendor offerings. The proposed generic model is a technology-agnostic strategy that was designed to be supported by standards-based communications. For development and operations, a prototype TIME system with a subset of the generic model features was deployed using the OpenADR 2.0 standard. The generic TIME system design included additional factors such as (1) generation variability posed by renewable resources such as solar and wind, (2) social costs in the form of GHG or carbon as determinants of the wholesale market price or cost, and (3) demand variability, as an additional determinant of the retail market price or cost.

No significant obstacles were encountered during the development of the TIME system or communication of TLM signals using a generic TLM pricing signal; however, integration with some independent projects required a higher level of technical support not anticipated in the original scope. The higher level of engagement was primarily with research teams without prior experience with OpenADR 2.0 standard.

Industry and research organizations that are well-positioned to use the study's results to develop new practices and value assessment could help achieve widespread adoption of economics-driven transactive technologies toward an integrated electric grid. For example, at the DR Symposium, Sacramento Municipal Utility District (SMUD) considered price innovation that includes supply-side markets, time of use (TOU) schedules, peak demand management, grid circuit capacity, and customer information, as some of the key determinants. DR resources could use the resulting price analytical system and database from the key determinants supporting the changing supply conditions.

Implementations by Demand Response Resources

The independent projects used the TIME system prototype to develop demand optimization and control models to lower the overall electricity costs for the participating customers. However, these independent projects did not evaluate the grid benefits, which were inherently assumed to be provided by the TIME system on the premise that TLM prices can represent the real system and market conditions and provide an economic incentive for DR resources. For example, a TLM price can be high when there is a lack of supply or excess demand or both, but a TLM price may be low when there is excess supply or low demand. A transactive price, if calculated accurately, would reflect a real-time electric grid system and market conditions. At the DR Symposium, PG&E highlighted the need for higher predictability and reliability from a DR program as a critical component for price analytics.

The results reported here are based solely on assessing the requirements of the eight independent project participants that participated in either the supply- or demand-side electricity markets. Analyses of the independent projects' signaling requirements show that the 24-hourly day-ahead California wholesale electricity market prices constituted the consensus temporal base case for TLM prices for those independent projects.

The independent projects' analyses also showed that the lowest desired spatial disaggregation for wholesale electricity price is the LMP published by the California ISO. The supply-side independent project participants used these as wholesale electricity TLM prices that reflected the LMPs at the APnode. Considering that the APnode prices for the IOU LAPs formed the lowest spatial disaggregation for retail electricity prices, the demand-side independent project participants used TLM prices with a price multiplier or a distribution price adjustment factor. In both instances, the California ISO day-ahead wholesale electricity markets provide a starting point for TLM prices that can use used to provide incentives to customers to manage energy use.

Integrated Transactive Load Management Signals for Demand Response Resources

In the regulated electricity markets in California, wholesale electricity markets are managed differently than retail electricity markets. A TIME system prototype of an integrated and inclusive approach with the California ISO (transmission and generation) domains and the electric utilities' (distribution) domain has the potential to determine "fair market" and integrated TLM prices. The prototype development and laboratory demonstration justify the expansion of the TIME research into field tests. At the DR Symposium, PG&E highlighted the need for better coordination across the California ISO, distribution operators, and DER operators to advance next-generation DR. At the same symposium, SCE highlighted the need for new models of integrated demand-side management that would require flexible end uses that meet shed, shift & shimmy services type requirements for California's grid needs and market resources. The suggestions by two of the three major California IOUs underscores the value of integrated TLM signal. In support of the GFO-15-311 requirements, the role of standardization of data models to communicate and interoperate with a diversity of DR resources and market participants was highlighted by the DR Symposium attendees.

The study concludes that the TLM price design must include various grid and customer data inputs for premarket planning and real-time analytics for supply- (wholesale) and demand-side (retail) markets, generation sources, and generation and demand variability. This design ensures that advanced analytics to determine TLM prices consider day-ahead supply planning and real-time grid operations. Here, the distribution system variability (demand/supply) adjustment for different electricity service providers could be considered for customer-level TLM system and prices that reflect generation- and distribution-integrated system and market conditions.

The interoperability principles for communications of TLM signals across a diversity of players and customer energy resources are critical for information exchange. Among the independent projects, a diversity of price-service interface (PSI) architecture was used to subscribe to the TLM prices. The PSI's existence outside a customer communications network (e.g., the vendor communication network) is an instance where the risk of vendor-dependency and lack of customer-level interoperability is higher. However, placing a PSI outside the customer communications network is not necessarily restrictive. It offers vendors the flexibility to offer value-added services (e.g., optimizing the use of energy resources to TLM prices) to customers grid operators. This need was evident in all the independent projects that used customer energy to participate in wholesale (supply-side) markets due to the complexities and rules required for integration with the California ISO systems. However, the pros and cons of interoperability considerations must be evaluated against individual implementations before an architectural decision can be made. SCE stated at the DR Symposium that, as California's electrification goals take shape, the value of DR using standards to engage the customers and facilitate the markets will become obvious.

Benefits to California and Ratepayers

The study provided the following benefits to California and its ratepayers. The benefits are aligned with the state's goals for the ratepayers (CPUC, 2012).

1. The TIME system's design and development and operations of a prototype system revealed the critical need to prioritize economic value and integrate California's supply- and demand-side electricity markets. Including generation variability, social costs from GHG emissions, demand variability, and supply- and demand-side markets can unlock the full value of customers' DR resources. The real-time application of the pricing constructs can potentially improve electricity reliability.

2. The study's TLM price signal structure, price analytics determination, demonstration of high-level architecture, and prototype system can enable DR participation for supply- and demand-side markets that will support California's aggressive renewable integration policies. Standardized approaches can improve the value of the technology enablement costs and enable customer-selected DR resources to integrate with electricity markets.

3. The TLM price signal design represents a real-time system and market conditions. As a result, the proxy price drives alignment of customer actions with grid needs. The grid operators can manage the grid reliability in real-time, with pricing at different locations and time-scales to safely operate the distribution assets (e.g., transformer capacity). The study showed that it is possible to design and deliver hourly prices to customers, their systems, and their devices—and that those customers can and do respond to those price signals while managing their individual preferences and safe equipment operating conditions. Thus, a proxy price representing the grid and market conditions could incentivize real-time load management behavior and increase grid reliability.

The results focus on the study's core objectives, and the benefits were derived based on the quantitative development and application of the TLM signals and the prototype TIME system. Evaluation of benefits to the customers and grid from the use of the TLM signals was outside the study's scope. The DR Symposium, which included independent projects and other stakeholders, was leveraged to qualitatively identify additional benefits.

Benefits Identified at the Demand Response Symposium

Expanding on the benefits, the project team solicited feedback from the DR Symposium participants through a survey that focused on research projects funded through GFO-15-311. These expanded benefits are presented in this sub-chapter. The full survey questions are listed in Appendix D.

As a DR resource, customer participation is moving toward "information-centric" principles, in contrast to earlier DR implementations that focused on "command and control." At the DR Symposium, SCE described the DR participation transitioning from a "command and control" to "informing and motivating" customers. For example, communicating prices or grid power requirements instead of temperature setpoint changes. Such principles are crucial in considering the DR program data models used by standards such as OpenADR 2.0 and IEEE 2030.5 or Smart Energy Profile 2.0 (IEEE 2018). A summary of benefits is as follows:

- The increasing use of digital voice assistants and advanced energy management systems in homes equips the residential sector with automation capability that has historically been cost-effective only for the commercial and industrial sectors. Such a transformation of digital technologies provides a technological foundation for enabling response to time- and location-varying prices.

- The use of TLM prices or similar pricing methods can help engage a diversity of DR resources cost-effectively by allowing customers to choose how and when to consume or conserve.

In addition to the recommendations for future research in**Error! Reference source not found.**, the market adoption of TLM prices through a better rate design can influence response over-generation conditions and not just under-generation.

Benefits Identified from the Survey Analyses

After the DR Symposium, participants responded to a brief survey on the future of DR and TLM signals. The results are presented in tables 2–4 below. The three survey questions that focused on the benefits of the research are listed below. Note that the survey questions were requested after the attendees were presented the study findings from all the independent projects.[4]

Table 2: Results from Survey Question #1 at Demand Response Symposium

Item	Description
Question	***What research would you recommend for advancing mainstream TLM-based signals and a TIME-like system to elicit DR?***
Response Categories	(a) Very Effective, (b) Somewhat Effective, (c) Not effective, and (d) I have a different perspective (explain).
Respondents	Fourteen (14)
Interpretation of Responses	A majority or eight (8) responded that the TLM signals were "somewhat effective" in increasing DR in California. One reason could be that not all independent projects used TLM signals to manage DR resources. The next high number of three (3) respondents said they had a "different perspective." Here, the common theme was the need to better understand the TLM principles relative to customer and grid benefits; Otherwise, they could be interpreted as "somewhat effective." There were outliers that TLM signals were "very effective" and "not effective" (one (1) and two (2), respectively) where respondents recorded multiple responses based on supply- or demand-side market independent project findings.
Conclusion	The responses point to the promising potential that TLM prices can bring to the California grid. At the same time, due to the early-stage research, the responses validated research findings that more data are required to elucidate TLM prices' effectiveness and understand the value the TIME or TLM system brings to the grid and customers.

Source: EPRI

[4] Note that the cumulative individual responses may exceed the total number of respondents since multiple answers were provided for some of the survey questions.

Table 3: Results from Survey Question #2 at Demand Response Symposium

Item	Description
Question	***Based on the research findings, how reliable are the TLM signals to manage integrated DR from optimized supply-side load resources (supply-side markets)?***
Response Categories	*(a) Very Reliable, (b) Somewhat Reliable, (c) Not Reliable, and (d) I have a different perspective (explain). Here reliability references communications and response from DR resources.*
Respondents	Fourteen (14)
Interpretation of Responses	Five (5) respondents said that the TLM signals were "very reliable," but five (5) others said that they required more data to ascertain reliability. While the communication's reliability can be well-established, some respondents were unsure if the DR resources can be "managed reliably." Other respondents said that TLM signals were either "somewhat reliable" or not reliable (two (2) each).
Conclusion	The responses validate research results that the TLM price communications using standardized signals were "very reliable." However, the reliability of response from DR resources is not well-known and needs further assessment. A careful review of findings from each of the independent projects should provide more details on this topic.

Source: EPRI

Table 4: Results from Survey Question #3 at Demand Response Symposium

Item	Description
Question	***Based on the research findings, how reliable are the TLM signals to manage integrated DR from optimized demand-side load resources (demand-side markets)?***
Response Categories	*The responses were requested in a multiple-choice format and included the same responses as requested in the second question from above (supply-side markets).*
Respondents	Fourteen (14)
Interpretation of Responses	A half or seven (7) respondents mentioned that the TLM signals were somewhat reliable, while four (4) other respondents mentioned that the TLM signals are very reliable. There were outliers that TLM signals were not reliable with two (2) respondents. Note that some recorded "very," "somewhat," and "not reliable" as responses, with comments that reflected conditions such as when aggregation is required to ascertain the reliability of DR responses and TLM signal communications are reliable. In hindsight, it would have been wise to separate these two questions in the survey.

Item	Description
Conclusion	The higher number of responses for using TLM signals for demand-side markets pointed to lesser reliability (somewhat reliable). These responses validate the research results that, most likely, due to the lack of close coupling of retail and wholesale market prices and the actuarial analysis of distribution prices, full reliability DR resources cannot be established. A prototype TIME system and simple distribution price adjustment method developed in the study may require advanced methods to determine a fair market value and increase customer responses.

Source: EPRI

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

This chapter summarizes the technology and knowledge transfer activities to disseminate research findings, solicit feedback from the industry leaders, and improve the results and recommendations.

Technology Transfer Activities

The study's TLM framework and pricing reference model were developed through a collaborative approach with the TAC and TAB members. The TAC was composed of the other independent projects who planned to test the TLM proxy price signal as part of their demonstrations; the TAB was composed of industry and public agency stakeholders and subject matter experts. A collaborative approach of technology transfer and feedback, which was required by GFO-15-311, was accomplished by information exchange with the TAC and TAB members for the study's duration. The activities included input at periodic meetings, requests for input on interim reports, surveys, and other feedback opportunities. The DR Symposium was hosted to provide a face-to-face opportunity for stakeholders and advisors to discuss the activities and findings from each of the independent projects, identify unanswered research questions, and propose key recommendations for the future research necessary to send the price signals to customers.

Technical Advisory Committee and Board

The TAC subject matter experts included the representatives from the GFO-15-311 group 1 and 2 independent projects, and the meetings were scheduled quarterly. The TAC was the primary source for day-to-day research updates for adjustments to the TLM framework, TLM signal design, and implementation models. The TAB members were national-level experts primarily from the public and California agencies (IOUs, California ISO, CPUC, CEC) who were engaged in less-frequent semi-annual meetings. The TAB members were the primary source to transfer the study findings and align California's research to the national goals. The study engaged the TAC and TAB members for the entire duration of the study. The TAC and TAB members and their affiliated organizations are listed in Appendix B.

The technology transfer through the TAC and TAB members' engagement enhanced the research outcomes and recommendations and identified key target markets for applications of the TIME system design. The technology transfer activities resulted in an adjustment to the TLM signal design and TIME prototype system development that accommodated the IOUs, California ISO, and the industry's needs. The study's technology readiness level (TRL) is in the range of 4 and 5 (DOE 2013) that focused on early-stage TLM system design and development through a prototype TIME system. The recommendations outlined in Chapter 5 are intended to transition the research to higher TRLs. The analysis of the findings from GFO-15-311 group 1 and 2 independent projects is outside the study scope, and the TRL assessment was conducted independently of this. The GFO-15-311 group 1 and 2 independent project participants were engaged in presenting their findings at the DR Symposium and reviewing the study outcomes.

Demand Response Symposium

In addition to the technology transfer activities conducted through TAC and TAB members, the study leveraged the DR symposium for the technology transfer activities and reviewed the research results. The DR symposium provided the research team with an opportunity to engage the key stakeholders to review the collective GFO-15-311 independent projects and provide recommendations for the future of California's TLM research. The stakeholders and organizations they represented are listed in Appendix C.

This DR symposium addressed the following key questions for each of the standalone, independent projects with an emphasis on supply- and demand-side markets:

- What did each project do?
- What were each project's results or findings?
- How did each project utilize the TLM signals.?
- What was learned?
- Based on the results or findings, what were the independent project teams' high-level recommendations for advancing the use of proxy price signals in general and TLM signals specifically?

Additionally, the key stakeholders and all the independent projects were leveraged to conduct a comprehensive survey that focused on the use and efficacy of the TLM system, what challenges can be posed, and the benefits provided by the TLM signals. The survey details and the results from the analysis are described in Chapter 3 and Chapter 5.

Knowledge Transfer Activities

Since the study focused on the TRLs in the range of 4 and 5, no comprehensive knowledge transfer activity was initiated. The TAC and TAB members, as mentioned earlier, and the DR Symposium were used as platforms for knowledge transfer. Specific knowledge transfer engagements included presenting the research objectives and preliminary findings in the national forums, as shown in Table 5.

Table 5: List of Forums Leveraged for Knowledge Transfer

Forum Name	Description
CEC's Integrated Energy Policy Report (IEPR) Commissioner Workshop on Demand Response	"The California Energy Commission Lead Commissioner for the 2017 Integrated Energy Policy Report (IEPR) will conduct a workshop to discuss the current status of progress in achieving California's demand response (DR) goals and opportunities and barriers for increased future DR participation." (IEPR 2017)
U.S. Department of Energy and GridWise Architecture Council's Transactive Energy Systems Conference and Workshop	"June 2017's fourth International Conference and Workshop on Transactive Energy Systems again brought together representatives of government, industry, utilities, vendor organizations, and academia to advance understanding and implementation of transactive energy systems." (GWAC 2017)
DistribuTECH International Conference	"DistribuTECH International is the leading annual transmission and distribution event that addresses technologies used to move electricity from the power plant through the transmission and distribution systems to the meter and inside the home." (DistribuTECH 2018)
Grid Analytics and Power Quality Conference and Exhibition	"The theme for this year's conference is Getting Actionable Intelligence from Big Data. As an integrated, more renewable-based, communication driven, dynamic power system emerges, utilities must be prepared at all levels for this transformation. The conference will provide a forum for electric power end users, distribution electric service providers, data managers, and power quality (PQ) professionals, to gather, share experiences, and learn from one another in a collaborative environment." (EPRI 2017).

Note: The description of the forum name is quoted from the managing organization's website.

Source: EPRI

The information obtained and the feedback received from these technology and knowledge transfer activities can assist the public organizations in changing policy, operations, or other regulatory barriers to increase the use of the transactive-based energy technology improvements and implementation in independent projects.

CHAPTER 5: Conclusions and Recommendations

From the design of the TLM signals and a TIME system, the Phase 1 research identified many benefits. The study leveraged this extant research to make recommendations and identify future research opportunities. These recommendations and opportunities are summarized in this chapter under (1) development of the TLM system and price communications to DR resources, and (2) overarching TLM research opportunities. Conclusions are presented as appropriate.

The recommendations and conclusions were derived from the study results. The future research opportunities were derived from the study results and survey responses conducted during the DR Symposium. Albeit the emphasis was on California electricity markets, the recommendations and opportunities could also be relevant to other regions.

Development of the System and Communications

One of the key objectives of the GFO-15-311 was to develop, test, and operationalize transactive signals that the IOU customers can use. The transactive incentive-signals to manage energy-consumption (TIME) study has successfully demonstrated the viability of a proxy TLM price signal design, construction, and use within California's regulated markets and operated a TIME system prototype to communicate with customer's DR resources. The recommendations from the development of a TLM system and communications of TLM signals to a customer's DR resources, as follows:

- TIME System and Signal Design: The study used the California ISO's day-ahead wholesale electricity market prices from LMP, LAPs, and SubLAPs, as proxy price indicators for supply-side DR markets. The integration of the TIME system and TLM signal design required customization to manage day-ahead wholesale market prices that are published in a random sequence— that is, prices are published in a non-standardized format with unknown processes. A case to handle the published prices on a "long day" at the start of a leap year required further research and implementation of a customized programming method to derive prices. As learned from the implementation of TLM prices from the GFO-15-311 independent projects, automating DR resources is required for a faster response. Automation plays a key role in ensuring customers are motivated to participate in DR programs. The experience with lack of standardization and known processes has emphasized that there is much to learn from the TIME system's long-term operations to ensure the reliability of TLM price communications. Such improvements eventually enable automated applications of a TLM system and TLM signal design.
- Size of the Pricing Data Models: While any communication standard can support the study TLM signal and TLM price design, the study used OpenADR 2.0 standard as a reference model. A known issue of the relatively large data size of the TLM model published with an OpenADR 2.0 standard (24-hourly intervals of day-ahead prices) challenged some of the independent projects to process the signals and optimize the

DR resources. Some of the independent project participants have indicated that they would have preferred to store TLM price signals for multiple days and could not do so due to insufficient memory in their client systems and larger data sizes. This issue is inherent in the design of the OpenADR 2.0 standard. While the data size and accompanying market information of a TLM signal with 24-hourly prices are not seemingly large, smaller devices such as thermostats, heat-pump water heaters, pool pumps, and so on, with constrained computing and storage resources can be challenged by historical tracking or non-repudiation requirements of the DR program. In another instance, in a TIME system's operation, the study discovered an issue with the OpenADR 2.0 server system that communicated the TLM prices. Whenever the independent project participant’s OpenADR 2.0 client systems requested the TLM prices, the server system, by default, also sent the historical TLM price messages that exacerbated the problem. By excluding the historical TLM price information from the request addressed this issue.

The findings show that optimization of data payload size is critical for successfully implementing a proxy price signal, its expansion to real-time price communications, and use by the constrained computing resources. Standards organizations should consider ensuring that data communications consider methods to optimize data size.

- Integrated system for DR resource communications: Some independent projects required additional support to integrate the OpenADR 2.0 client system; the project team had not anticipated this. Overall, there could have been many more challenges if the TLM price signals had not been published using a standards-based approach. Evidence from the independent projects suggests that demand for automation technologies is triggered when customers are provided a reasonable value proposition for DR participation.

  In the future, the CEC could ensure that the system integration challenges are the independent project's responsibility or enforce the requirement of interoperability certification to increase the efficiency of systems integration. The study used the OpenADR 2.0 standard to communicate TLM prices to all DR resources. In reality, a diversity of DR resources such as EVs, energy storage systems, and end-use loads, all use different communication standards, optimization techniques, and control methods to meet the customer or grid objectives. This scenario requires expanding the prototype TIME system to a common platform to harmonize communications from a diversity of standards and DR resources. At the DR Symposium, PG&E emphasized a need for an integrated system to communicate the prices and harmonize standards for cost-effective interoperability across grid systems.

Overarching Opportunities

The following research opportunities were identified through the engagement of TAC and TAB members and key stakeholders at the DR Symposium.

- TLM-Centric Research Roadmap: As addressed in the earlier recommendations, an immediate opportunity is to develop a comprehensive roadmap that identifies and recommends a specific course of action for TLM research to support California’s clean energy policies. Such a roadmap would include the engagement of crucial stakeholders composed of grid operators, the CEC, the CPUC, the California ISO, electric utilities, and other organizations. Such a roadmap would identify the additional existing research, review different transactive approaches, and list tangible research recommendations. This roadmap can support California's vision of a more transactive grid that benefits the grid and the ratepayers.

- Value Assessment of the TIME System: A critical question that emerged from the expert stakeholder feedback is: How should the value to grid and customers from the development and implementing a real-time pricing system be assessed? The study's scope was focused on designing a TIME system and the development and operation of a prototype system to communicate TLM prices. While the study achieved this goal successfully, to attain the vision of a pricing structure that effectively communicates grid conditions, carbon emissions, and system costs as envisioned in the solicitation, a quantitative value assessment should be conducted, and regulatory constraints and expectations should be reevaluated. The indicators for value assessment can be any the following: improvements in system reliability, cost-savings, GHG or carbon abatement through high penetration of bulk and distributed renewable generation, fixed-cost recovery, transmission, distribution cost deferrals, and others.
- Analyze and Develop Methodologies for TLM Prices: The study leveraged the Pnode LMPs for wholesale electricity market prices and proposed a simple methodology for the distribution system adjustment for a prototype TIME system. A comprehensive evaluation of methodologies that determine the distribution system adjustment should be conducted to develop methodologies to represent the electricity system and market conditions more accurately and to identify those automation technologies that consumers can use beneficially to manage their loads. The California utilities (e.g., SDG&E, SCE) are developing early-stage methodologies to determine distribution system adjustments. These methods could be evaluated, as a starting point, to become an integral part of the value assessment TLM principles.
- Development of the System and Price Analytics: A prototype TIME system was developed to support the GFO-15-311 goal of providing an example prototype to determine and publish TLM prices in a standardized format. The continued development of TLM research and operation of the TLM system depends on the independent projects. There is an opportunity to leverage the prototype system to develop price models and analytics that incorporate different transactive models to determine the distribution system price adjustment. California's IOUs are researching this area and can benefit from expanding the TIME system study. The inclusion of different transactive models and relating them to the utility fixed cost revenue recovery can help with the market applications of TLM methods.

Opportunities Identified at the DR Symposium

In addition to reviewing the benefits from the survey conducted during the DR symposium, the project team solicited feedback from the DR symposium participants through a survey to identify new research opportunities. The research opportunities identified from the analysis of the survey results are presented here. The survey questions are included in Appendix D**.**

The research opportunities identified at the DR Symposium are categorized under three core research areas: (1) TIME System and TLM Research, (2) Customer and DR Resource Engagement, and (3) Other Related Areas. They are described in more detail below.

TIME System and TLM Research

Considering the DR Symposium's focus was to understand the linkages between the independent projects and the TLM research, it is not surprising that most opportunities focus on California's TLM research. These opportunities are as follows:

- Review the role of TLM prices in predicting and real-time understanding of the grid system and market conditions, including any resulting changes in customer demand and grid reliability, which is currently unclear.
- Conduct analyses to better understand how the TLM signal design and TIME system analytics can affect the existing distribution system's electricity rate tariffs and how transactive approaches can influence several DR resources' flexible management.
- Ensure the research demonstrates (1) cost-savings to the ratepayers and (2) grid benefits across seasons and diversity of generation profiles and responsive technologies or the technologies that engage customer and DR resources for grid management.
- There is a lack of a business model to monetize the benefits. While this could be a "chicken-and-egg" problem, the initial value assessment of TLM approaches can be used by the key stakeholders to develop a viable business model for customers.
- Automation facilitates higher customer participation rates and higher per-customer levels of response and improves that response's reliability. It also is critical to the development of agile, scalable, reliable, flexible load resources. It is essential to review system architecture and market models and identify what role technologies, communications, and interoperability standards play in effectively supporting the expanded inclusion of flexible load in grid operations.
- In the context of interoperability standards, when considering a diversity of customer DR resources and technologies, solutions must propose harmonization for a diversity of communication protocols and standards (e.g., loads, EVs, energy storage).
- Review systems, communications, controls architecture, and services that support DR resources' participation in supply-side markets. Develop a roadmap that includes a research plan, methodology, and strategy for further TLM research that includes some of the critical opportunities mentioned above. Classification can include state- and utility-level roadmaps that consider strategies for different TLM technologies that promote California's clean energy future and grid reliability needs.

Customer and DR Resource Engagement

While the opportunities to engage customers and DR resources are covered in the previous sub-chapter, TIME System and TLM Research, the opportunities noted here are specific to customer and DR resource engagement. These opportunities are summarized as follows:

- Concern was expressed that DR service offerings are not expanding and are supported by the private sector. Here, value streams from market models (e.g., market reform) must be identified so that the private sector can develop technologies and offer products and services to customers and utilities.

- A TLM Pricing system would provide a clear signal to customers on the economic value of the load reductions they provide and eliminate the complex and costly process of estimating baselines and processing ex-post load reduction incentive payments. Measuring and verifying DR performance or baseline methods is a longstanding issue for managing and scaling DR. Baseline estimation is imperfect. It results in effectively discounting customer or grid impacts and the value customers receive from their efforts. While research on accurate and efficient methods to measure and verify DR performance may be justified, TLM prices resolve the baseline issues since price becomes the metric to assess customer performance.
- Among a diversity of DR resources, energy storage and EVs provide maximum flexibility for responding to time-varying prices. Research should review how energy storage and different energy storage technologies, including EVs, can add value to TLM approaches since they can offer more flexible DR engagement options to customers.

Other Related Areas

Separate from the TLM techniques and customer DR resource engagement, other related opportunities are identified that are summarized below.

- Evaluate and develop forecasting approaches that consider new flexible loads concerning DR resources such as distributed generation, energy storage, and EVs.
- Assess EVs as flexible moving loads with TLM pricing models that can mitigate or alleviate overloading of circuits or a sub-station network.
- Develop proof-of-concept demonstrations at different grid levels with key players.
- Assess the impact of TLM approaches on customer comfort and behavior and disadvantaged or low-income communities to develop awareness and scale adoption.

Opportunities Identified from the Survey Analyses

Of the seven questions in the survey conducted during the DR Symposium, the final four questions focused on identifying the new research opportunities. The results from the survey analyses are summarized in Tables 6–9 below. The survey responses were requested after the attendees were presented the study findings from all independent projects.[5]

[5] The cumulative individual responses may exceed the total number of respondents since multiple answers were provided for some of the survey questions.

Table 6: Results from Survey Question #4 at Demand Response Symposium

Item	Description
Question	***Based on the research findings, how effective are the TLM signals in increasing demand response from DERs in the California grid?***
Response Categories	*(a) Enough research has been done to prove TLM signal effectiveness, (b) More research is needed to understand the effectiveness of TLM signals, (c) Better understanding of the economics for TLM signals is needed, (d) More research is needed to prove the value to the consumer, (e) More research is needed to prove the value to the grid, and (f) Something else (explain).*
Respondents	Sixteen (16)
Interpretation of Responses	Five (5) responded that further research would be required to prove the TIME system's value to the grid and the consumer. This finding aligns well with the qualitative research recommendations to develop a TLM research roadmap for California and conduct a value assessment of the TIME system. The next most common response was that respondents would like to understand the TLM signals' economics better, and more research is needed to understand the effectiveness of TLM signals.
Conclusion	These responses indicate that: (1) the development of methodologies that accurately represent the wholesale and distribution system market prices, and (2) the effective use of TLM signals by the consumers and the automation technologies are critical to further the TLM vision in California. These identified opportunities align with research findings. Here, further research would be required for methodologies to determine wholesale and distribution system prices and how consumers can use them through TLM signals and data models. Other responses included: to conduct further research to understand the increased reliability and predictability of supply and demand conditions, to consider inverter-based DR resources and related standardized data models, and that the extant research proves the effectiveness of TLM signals.

Source: EPRI

Table 7: Results from Survey Question #5 at Demand Response Symposium

Item	Description
Question	***What, in your opinion, must California stakeholders do to mainstream TLM-centric business models?***
Response Categories	*(a) Utilities and ISO must operationalize TLM research findings in their business models, (b) Regulatory support will be needed to realize the societal benefits of the TLM signal, (c) Focused applied research and field testing will be needed before the business value can be determined, (d) Technology vendors must offer innovative solutions to increase the*

Item	Description
	reliability of DR in supply and demand-side markets, and (e) Something else (explain).
Respondents	Sixteen (16)
Interpretation of Responses	Seven (7) respondents said that regulatory support to realize TLM signals' societal benefits is essential. This finding aligns well with the regulatory intervention recommendation to determine the TIME or TLM system's value assessment. The next highest number of respondents (four (4)) said that the utilities and ISO must operationalize the TLM research findings in their business models and that focused applied research must assess the business value.
Conclusion	The responses validate the overarching approach used by the GFO-15-311 to engage grid operators and conduct field tests. Additional simulated laboratory-based tests and field tests of TIME system and value assessment approaches are key to engage grid operators and identify the business value. The outliers included engaging technology vendors to offer innovative solutions and the inclusion of inverter-based DER resources in the TLM research assessment.

Source: EPRI

Table 8: Results from Survey Question #6 at Demand Response Symposium

Item	Description
Question	***How important are interoperability standards in energy systems integration using a TLM-centric approach?***
Response Categories	*(a) Important, (b) Somewhat important, (c) Not important, and (d) I have a different perspective (explain).*
Respondents	Sixteen (16)
Interpretation of Responses	A majority of thirteen (13) respondents said that the TLM research must consider interoperability standards and consider integrating energy systems that include both wholesale and retail side electricity markets. The outliers suggested that such an approach is "somewhat important," which still emphasized the need. An explanation included the development and consideration of standardized data models in addition to OpenADR 2.0, which was used as a reference data model in this study.
Conclusion	It is clear from the responses that interoperable communications and standards play a critical role in the integrated TLM prices and systems. The responses also validate the research approach of developing the TLM signals and prices to support different communication standards.

Source: EPRI

Table 9: Results from Survey Question #7 at DR Symposium

Question	***How important is it to design a system that leverages advanced methods and analytics to combine real-time system information with forecasts of loads (demand) and distributed generation (DG) production?***
Response Categories	*The responses were requested from a multiple-choice format and included the same responses as requested in Question 6 above.*
Respondents	Sixteen (16)
Interpretation of Responses	A majority of fourteen (14) respondents said that the TIME system design must leverage advanced methods and data analytics that integrates wholesale and retail systems and develops the forecasting and real-time information system that includes both demand and variable bulk and distributed generation. This recommendation is at the core of the TLM research that determines the accurate system and market conditions and the design considerations of new TLM price determinants supporting California's future clean energy system. Two (2) respondents suggested that such an approach is "somewhat important," which still emphasized the need and the need to go beyond load management to develop data models that consider grid systems.
Conclusion	The data analytics and methods to determine the supply-side TLM prices- and the demand-side market are required. The responses validate the study's findings on the importance of TLM signal design and TLM system framework to determine the price based on system and market conditions.

Source: EPRI

Overarching Conclusions

There is an immediate need to address technical, regulatory, and business challenges to motivating IOUs, customers, and vendors to develop and apply TLM principles to integrate supply- and demand-side markets. These challenges expand beyond TLM research and span across many areas to enable integrated and inclusive market-based prices or integrated TLM prices. These challenges include but are not limited to (1) managing DR resources and customer engagement in supply- and demand-side DR programs, (2) evaluating the role of digital technologies to optimize DR resources for long-term and real-time grid operations, and (3) reforming the markets to incentivize businesses and customers. The CEC should develop a roadmap to evaluate utility business models' impacts and assess technologies that adjust the wholesale electricity prices to produce a distribution system price based on real-time system and market conditions. Additionally, research must focus on identifying benefits to the grid and customers and developing technologies and analytical framework to adjust wholesale electricity prices to produce a distribution system price based on the real-time electricity system and market conditions.

Overall, the research findings, recommendations, and opportunities from the study point positively toward California's vision to advance TLM-centric research. Simultaneously, to determine the practical application, it will be critical to developing integrated grid models and value assessments that include grid operators and customers. This study has made strategic recommendations and identified opportunities that the CEC and other California agencies can leverage to determine the next TLM research stages for California.

REFERENCES

California Air Resources Board (CARB). *Assembly Bill (AB) 32 Overview*. September 2018. Available at https://ww3.arb.ca.gov/cc/ab32/ab32.htm.

California Energy Commission (CEC). 2015. Grant Funding Opportunity (GFO): Advancing Solutions that Allow Customers to Manage their Energy Demand, GFO-15-311. December. Available at http://www.energy.ca.gov/contracts/GFO-15-311/.

California Independent Systems Operator (CAISO). 2019a. *Business Practice Manual for Generator Interconnection and Deliverability Allocation Procedures.* October. Available at https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Generator%20Interconnection%20and%20Deliverability%20Allocation%20Procedures.

California Independent Systems Operator (CAISO). 2019b. "Demand Response and Load Participation." Accessed in November 2019 at http://www.caiso.com/participate/Pages/Load/Default.aspx.

California Independent Systems Operator (CAISO). 2019c. "Market Processes and Products." Accessed in November 2019 at http://www.caiso.com/market/Pages/MarketProcesses.aspx.

California Independent Systems Operator (CAISO). 2019d. "Open Access Same-time Information System (OASIS)." October. Available at http://oasis.caiso.com/mrioasis/logon.do.

California Independent Systems Operator (CAISO). 2013. "Fast Facts: What the Duck Curve Tells Us About Managing a Green Grid." Folsom, California.

California Public Utilities Commission (CPUC). May 2012. "Phase 2" Decision 12-05-037. Available at http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.

DistribuTECH. 2018. Transforming Power. January. Available at https://www.distributech.com/event-information/post-event-report.html.

Electric Power Research Institute (EPRI). 2017. Grid Analytics and Power Quality Conference and Exhibition: Getting Actionable Intelligence from Big Data. June. Available at https://www.epri.com/#/pages/event/1056C555-4904-4058-BB01-F404458C0957?lang=en-US.

Electric Power Research Institute (EPRI). Transactive Incentive-signals to Manage Energy-consumption (TIME): The System- and Market-Based Transactive Load Management (TLM). EPRI, Palo Alto, CA: 2018. 3002012290.

Electric Power Research Institute (EPRI). Residential Battery Energy Storage: Demand Response Opportunities with OpenADR 2.0b— Field Deployments and Performance Analysis. EPRI, Palo Alto, CA: 2020. 3002017985.

Ghatikar. G, J.L Mathieu, M.A. Piette, S. Kiliccote, Open Automated Demand Response Technologies for Dynamic Pricing and Smart Grid, Grid-Interop Conference, December 2010. LBNL-4028E. DOI 10.13140/2.1.2721.6162.

Ghatikar G. and E. Koch, Deploying Systems Interoperability and Customer Choice within Smart Grid, Grid-Interop Conference, December 2012. LBNL-6016E. DOI 10.13140/2.1.5162.8320.

Ghatikar, G., and W. Johnson. 2017. *Transactive Incentive-signals to Manage Energy-consumption (TIME): The System- and Market-Based Transactive Load Management (TLM).* EPRI. Palo Alto, California. 3002012290. Available at https://www.epri.com/#/pages/product/000000003002012290/.

Greenstone, M., and I. Nath. 2019. Do Renewable Portfolio Standards Deliver? Energy Policy Institute at the University of Chicago. NO. 2019-62 Available at https://epic.uchicago.edu/wp-content/uploads/2019/07/Do-Renewable-Portfolio-Standards-Deliver.pdf

GridWise Architecture Council (GWAC). 2017. "Fourth International Transactive Energy Systems Conference & Workshop, Maximizing Your Value: What Can Transactive Energy Systems Do for You?" TESC Proceedings. June. PNNL-SA-131679.

Institute of Electrical and Electronics Engineers (IEEE). 2018. 2030.5-2018: IEEE Standard for Smart Energy Profile Application Protocol. Available at https://standards.ieee.org/standard/2030_5-2018.html.

Integrated Energy Policy Report (IEPR) Commissioner Workshop on Demand Response. 2017. California Energy Commission (CEC). Available at https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2017-integrated-energy-policy-report/2017-iepr.

LegInfo (Official California Legislative Information.) 2002. California Renewable Portfolio Standards, Senate Bill (SB) No. 1078. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200120020SB1078.

LegInfo (Official California Legislative Information. 2006. Assembly Bill (AB) No. 32 (Nuñez, Chapter 488, Statutes of 2006). Available at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.

LegInfo (Official California Legislative Information.) 2011. California Renewable Portfolio Standards, Senate Bill (SB) No. X1-2 (Statutes of 2011, first extraordinary session, chapter 1). Available at http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0001-0050/sbx1_2_bill_20110412_chaptered.html.

LegInfo (Official California Legislative Information.) 2015. California Clean Energy and Pollution Reduction Act, Senate Bill (SB) No. 350 (Chapter 547). Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

OpenADR Alliance. 2019. "OpenADR Certification Process." November. Available at https://www.openadr.org/certification-process.

OpenADR Alliance (OpenADR). 2013. "OpenADR 2.0 Profile Specifications: A and B Profiles." Available at https://www.openadr.org/.

U.S. Department of Energy (DOE), Office of Environmental Management. 2013. *Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Implementation Guide: Revision 1.* August.

U.S. Energy Information Administration (EIA). 2017. Electricity Data Browser, Average Retail Price of Electricity. Accessible at https://www.eia.gov/electricity/data.php.

U.S. Energy Information Administration (EIA). 2020. Average Price of Electricity to Ultimate Customers by End-Use Sector. Accessible at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
APnode	Aggregated Pricing Node
California ISO	California Independent System Operator
CPUC	California Public Utility Commission
DR	Demand Response
DG	Distributed Generation
DERs	Distributed Energy Resources
EV	Electric Vehicle
GW	Gigawatt
GHG	Greenhouse Gas
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
kW	Kilowatt
kWh	Kilowatt-hour
LAP	Load Aggregation Point
LMP	Locational Marginal Price
MWh	Megawatt-hour
OASIS	Open Access Same-time Information System
OpenADR	Open Automated Demand Response
PQ	Power Quality
Pnode	Pricing Node
PSI	Price Services Interface: The demarcation point between the grid Transactive System and consumers is the final recipient of the standardized TLM data models.[6]
SEP 2.0	Smart Energy Profile 2.0
Sub-LAP	Sub Load Aggregation Point

[6] Adapted from the National Institute of Standards and Technology (NIST) term, Energy Services Interface (ESI), which is the "device or application that functions, as the gateway between the energy providers and consumers." (NIST Special Publication 1108r3; NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0. September 2014).

Term	Definition
TRL	Technology Readiness Level
TOU	Time of Use
TIME	Transactive Incentive-signals to Manage Energy-consumption: A system and methodologies used to develop an integrated and inclusive TLM framework used for the design and development of a prototypical TLM signaling and management system.
TLM	Transactive Load Management: A method used to leverage flexibility through demand response (DR) strategies using economic incentives (that is, electricity prices) and advanced energy technologies as a proxy for customer response.[7]
TLM Data Models	Transactive Load Management Data Models: Representation of Transactive Signals components in a machine-readable and potentially standardized format.
TLM Prices	Transactive Load Management Prices: Spatial and temporal energy and power prices within the Transactive System and markets determined based on the actual system and market conditions and used, specifically, for TLM.
TLM Signals	Transactive Load Management Signals: Taxonomy, data construct, and/ or transport mechanisms used to communicate the Transactive Prices to customers using methods such as the Internet.
TLM System	Transactive Load Management System: An advanced TIME system that combines real-time system information with forecasts of loads (demand) and distributed generation (DG) production to develop an economic incentive or price (TLM) “signal” that reflects real-time system and market needs.

[7] California Energy Commission Grant Funding Opportunity (GFO) Advancing Solutions that Allow Customers to Manage their Energy Demand. 2015. GFO-15-311. December.

APPENDIX A: Summary of GFO-15-311 Independent Projects

Table A-1 summarizes the GFO-15-311 eight independent projects and their objectives that led to the development of the TIME system and TLM prices framework. A briefing for these projects that were obtained from the CEC is also included for reference.

Table A-1: Summary of GFO-15-311-Related Independent Projects and Objectives

Lead Organization	Project Objectives
BMW NA	EV smart charge management and optimization based on cost and carbon savings.
Center for Sustainable Energy (CSE)	Demonstrate the resource model for California ISO Proxy DR (PDR).
OhmConnect	Generate load changes from large numbers of residential customers at specific times and in specific geographic areas.
Alternative Energy Systems Consulting (AESC)	Demonstrate optimization of residential energy consumption based on day-ahead hourly pricing posted to the HEMS or aggregation.
California Institute of Energy and Environment (CIEE)	Use real or projected prices to initiate control sequences in small to large commercial building HVAC, lighting, and plug loads.
Electric Power Research Institute (EPRI)	Demonstrate aggregation of various load types and products for residential and small- and medium business (SMB) customers.
University of California Los Angeles (UCLA) Luskin Center	Study how consumer response to incentives varies with the weather, the day of the week, and time of day.
Universal Devices	Demonstrate residential and commercial automated and self-managed energy use and storage.

Briefing on the Independent Projects (the EPC-xx-xxx is the CEC contract number)

EPC-15-045

Project Name: Transactive Incentive Signals to Manage Electricity Consumption for Demand Response [EPC-15-045]	
Recipient/Contractor: Electric Power Research Institute, Inc.	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 5/18/2016 to 6/28/2019
Program Area and Strategic Objective: Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: Demand response (DR) has substantial potential to act as either a demand-side or a supplyside resource. However, existing programs and rates do not provide a participation incentive structure that accurately reflects system conditions or system costs, a suboptimal situation that results in higher ratepayer costs, low DR participation and an inability for system operators to regularly utilize demand-side resources. As the state moves toward more distributed generation and intermittent renewable energy generation, integration of those generation resources will further increase costs in the absence of significantly expanded DR resources responding to actual system needs in real time.	
Project Description: This project develops Transactive Load Management (TLM) signals, expressed in the form of proxy prices reflective of current and future grid conditions, and develops and implements software to calculate such signals. These signals are being designed to provide customers sufficient information to optimize their energy costs by managing their demand in response to system needs. The signals are transported via proven and available protocols and networks for use by projects that will test the efficacy of the TLM signals using the demand response projects awarded under GFO-15-311, Advancing Solutions that allow Customers to Manage Their Energy Demand.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project has developed a day-ahead hourly proxy price signal that incorporates system conditions as reflected by wholesale energy markets. The hourly prices are being made available on a publicly-accessible server and are being incorporated as one of the experimental pricing structures being evaluated in EPIC demand response projects funded under GFO-15-311 in order to assess the potential for a variety of different loads and	

customer types to respond automatically to a real-time proxy pricing signal, and by extension, the potential of DR being a demand side or a supply side resource for the State.

CPUC Proceedings addressing issues related to this EPIC project: Alternative Fueled Vehicles: R.13-11-007 Smart grid: R.08-12-009 [closed] Customer Data Access Program: Applications A.12-03-002, 003, 004. Decisions D.11 Distribution Level Interconnection (Rule 21): R.11-09-011 [closed] Demand Response (DR): R.13-09-011 Net energy metering: R.14-07-002 Resource Adequacy (RA) 2016 and 2017 Compliance Years: R.14-10-010 [Closed] Integration of Distributed Energy Resources (IDER): R. 14-10-003 Integrated Resource Planning and Long-Term Procurement Proceeding. LTPP (2016) cycle: R.16-02-007: R.16-02-007	
Applicable Metrics: CPUC Metrics- 1c, 1d, 1e, 1f, 1g, 1h, 3c, 3e, 3f, 3h, 4a, 5a, 5b Lower Costs: Demand response lowers costs for both the system and individual customers. Procurement costs are reduced when wholesale energy prices are attenuated by price-responsive demand; customer costs are reduced when they either shift consumption to lower-priced times or receive payment for participating load reduction. Greater Reliability: High levels of demand can stress grid assets, and increased stress could lead to outages if left unchecked. To the extent that a TLM signal and smart management of consumer loads can minimize stress on grid equipment, reliability is improved.	
Assignment to Value Chain: Grid Operations/Market Design	**Total Budgeted Projec t Admin and Overhead Costs:** $126,585
EPIC Funds Encumbered: $498,054	**EPIC Funds Spent:** $259,071
Match Partner and Funding Split: Greenlots: $110,450 (18.2 %)	**Match Funding:** $110,450
Leverage Contributors: **N/A**	**Leveraged Funds:** $0

Funding Method:	**Funding Mechanism:**	**No. of Initial Passing Applicants/ Bidders:**	**Rank of Selected Applicant/ Bidder:**
Competitive	Grant	19 out of 21 bidders	Group 3: Ranked # 1
If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.			

Treatment of Intellectual Property:

Pre-existing intellectual property identified in agreement EPC-15-045 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

Update:

The project is on schedule and will be completed in the first Quarter of 2019. The reference design for the Transactive Load Management signal was implemented in early 2018 and has been providing the 24-hour ahead real-time signal continuously since then. All interim deliverables have been received and the draft Final Report is expected January 30, 2019.

EPC-15-084

Project Name: Total Charge Management: Advanced Charge Management for Renewable Integration [EPC-15-084]	
Recipient/Contractor: Bayerische Motoren Werke of North America, LLC	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 6/30/2016 to 3/31/2020
Program Area and Strategic Objective: Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: Smart charging is a means of managing charging within a particular charging or parking event, usually at work during the day or at home during the night. The future electricity grid will face new balancing needs that change throughout the day and night as utilities and grid operators attempt to align renewable generation with customer load. As the grid becomes more dynamic, optimizing vehicle charging will require moving charging from night to day, from hour to hour, or from one grid location to another. California's steadily increasing electric vehicle population with larger capacity batteries combined with the mandates for more renewables require more means for managed vehicle charging.	
Project Description: This project explores the benefits and opportunities of Total Charge Management, where electric vehicle charging is managed across multiple charging events to maximize vehicle load flexibility. The project tests how flexible electric vehicle load can be if managed across a driver's daily or weekly charge events. This flexibility utilizes several pricing mechanisms to estimate the benefits of the Total Charge Management approach. The research develops and evaluates advanced vehicle telematics for utilities and grid operators to align vehicle battery status, driver mobility needs and grid conditions. Collaboration between the grid and the driver can yield a charging load profile that minimizes energy costs by aligning daily and weekly charging events to best meet grid needs.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will help the state advance the flexibility of electric vehicle charging as a flexible grid resource and vehicle charging cost savings to the driver. Optimal charging load patterns will be identified that can capture ratepayer and grid benefits using a variety of grid price signals. The project will pioneer demand response and smart charging technology	

advancement of not only the temporal benefits of controlled charging, but also the possible benefits that can be derived from being able to influence the location of charging.

CPUC Proceedings addressing issues related to this EPIC project: Alternative Fueled Vehicles: R.13-11-007 Demand Response (DR): R.13-09-011	
Applicable Metrics: CPUC Metrics- 1g Lower Costs: The cost of Plug-in Electric Vehicle (PEV) ownership is estimated to fall by $500 per year through grid service payments and reduced electricity bills for PEV drivers through managed charging. In total, this would provide $4,000 in savings over the 8-year ownership life of a typical vehicle. Greater Reliability: Total Charge Management would represent a resource of over 10,000 MWh per day. If 40 percent of that load could be flexibly managed, the following benefits would be realized every day: 3,000 MWh of solar-following load (enough to accommodate 4 million additional solar panels on the grid), and 1,200 MWh of wind-following nighttime load. Environmental Benefits: Aligning vehicle charging with renewable energy generation has the potential to reduce carbon emissions associated with vehicle charging by as much as 660,000 metric tons per year, at a scale of 1.5 million vehicles. Energy Security: Greater energy security comes from having more diverse distributed resources able to respond to grid needs. The Total Charge Management approach helps utilities and CAISO get more functionality out of electric vehicle load as a grid resource, which contributes to energy security.	
Assignment to Value Chain: Demand-side Management	**Total Budgeted Project Admin and Overhead Costs:** $207,398
EPIC Funds Encumbered: $3,999,900	**EPIC Funds Spent:** $1,034,708
Match Partner and Funding Split: Kevala, Inc.: $33,545 (0.8 %) BMW of North America, LLC: $378,386 (8.6 %)	**Match Funding:** $411,931

<table>
<tr><td colspan="2">Leverage Contributors:
N/A</td><td colspan="2">Leveraged Funds: $0</td></tr>
<tr><td>Funding Method:
Competitive</td><td>Funding Mechanism:
Grant</td><td>No. of Initial Passing Applicants/ Bidders:
19 out of 21 bidders</td><td>Rank of Selected Applicant/ Bidder:
Group 1: Ranked # 1</td></tr>
<tr><td colspan="4">If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.</td></tr>
<tr><td colspan="4">Treatment of Intellectual Property:
Pre-existing intellectual property identified in agreement EPC-15-084 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

The existing iCharge Forward program developed trade secrets related to the vehicle telematics system and software used to administer grid service functionality between BMW's software backend and BMW electric vehicles. These trade secrets will be applied in this CEC project.</td></tr>
<tr><td colspan="4">Update:
BMW optimized their smart charging using grid pricing and constraints tests for residential night time charging with 50 drivers, which will guide the expansion to away-from-home charging and daytime charging (locational marginal pricing and renewable generation). Kevala (subcontractor) developed and integrated a tool to identify the subLAP (sub-load aggregation point) and LMP node locations to facilitate vehicle charging management when vehicles are away from home. BMW identified, permitted, and installed four energy storage systems to begin implementing the energy storage and combined use cases. The project team completed a distribution constraint analysis to inform use case implementations in 2018. BMW presented a project overview, methodology, and preliminary results to partners in Europe.</td></tr>
</table>

EPC-15-074

Project Name:	
Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems [EPC-15-074]	
Recipient/Contractor: Center for Sustainable Energy	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 5/18/2016 to 12/31/2019
Program Area and Strategic Objective: Applied Research and Development; S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: The State of California has established aggressive goals for incorporating behind-the-meter, customer-sited distributed energy resources (DERs) into the California wholesale energy markets, managed by the California Independent System Operator (California ISO). However, with only limited testing performed to date, the ability of DERs to simultaneously and costeffectively meet onsite customer electrical needs while providing energy services into the California ISO market is largely unproven.	
Project Description: This project develops co-optimization strategies for distributed energy resources (DERs). The purpose is to maximize customer and system value under existing CPUC-approved retail and California Independent System Operator (California ISO) wholesale tariff structures, future market structures and pricing, and the transactive energy pricing signals developed under agreement EPC-15-054. The project tests and configures two DER portfolios: a) one consisting of large retail customers and schools using battery energy storage, solar photovoltaics, and integrated load management, and b) the other consisting of hotels using passive thermal energy storage, and energy efficiency. Both will be included as part of an integrated load management strategy capable of responding to price and reliability signals. The project team is also developing operational strategies for wholesale integration subject to the identified retail and wholesale tariffs and other operational constraints.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The project is developing and testing strategies that customers, demand response (DR) aggregators, scheduling coordinators, and policy makers can implement to provide demand response that both meets grid needs and is acceptable to customers. The project will provide	

comprehensive recommendations on how to overcome technical, institutional and regulatory barriers to facilitating DER participation in supply-side markets.
CPUC Proceedings addressing issues related to this EPIC project: Renewables Portfolio Standard: R.11-05-005 [closed], R.15-02-020 [Closed] Energy storage: R.15-03-011 [Closed] Smart grid: R.08-12-009 [closed] Customer Data Access Program: Applications A.12-03-002, 003, 004. Decisions D.11 Distribution Resources Plans (AB 327): R.14-08-013 Distribution Level Interconnection (Rule 21): R.11-09-011 [closed] Demand Response (DR): R.13-09-011 Net energy metering: R.14-07-002 Integration of Distributed Energy Resources (IDER): R. 14-10-003 Integrated Resource Planning and Long-Term Procurement Proceeding. LTPP (2016) cycle: R.16-02-007: R.16-02-007 Energy Efficiency Strategic Plan update and action plans: EE Strategic Plan docs Energy Efficiency Proceedings: R.13-11-005, R. 12-01-005, R.09-11-014 [Closed]
Applicable Metrics: CPUC Metrics- 1c, 1d, 1e, 1f, 1g, 1h, 3e, 3f Lower Costs: This project has the potential to lower energy costs for individual customers, as well as system costs for all ratepayers California ISO market participants. On the distribution circuit, demonstrated demand management capabilities can help defer cost of expensive capacity upgrade investments such as transformer or line upgrades. Greater Reliability: As the penetration of intermittent resources increases in California, energy balancing requirements increase as well. Behind-the-meter demand response and storage on the distribution system can increase distribution system reliability issues through services such as local overload relief, power quality and ramp-rate mitigation on circuits with high penetration of photovoltaics. Increase Safety: By deploying, testing, and validating system integration, metering, and telemetry, the project will contribute to the safe operation of DER systems in customer-sited locations while maximizing value for these systems to both customers and wholesale market activities.

Assignment to Value Chain: Grid Operations/Market Design	**Total Budgeted Project Admin and Overhead Costs:** $746,794
EPIC Funds Encumbered: $3,960,805	**EPIC Funds Spent:** $1,632,876

<table>
<tr><td colspan="2">Match Partner and Funding Split:
Solar City Corporation: $1,449,262 (24.4 %)
DNV GL: $2,000 (0.0 %)
Conectric Networks, LLC: $530,000 (8.9 %)</td><td colspan="2">Match Funding: $1,981,262</td></tr>
<tr><td colspan="2">Leverage Contributors:
N/A</td><td colspan="2">Leveraged Funds: $0</td></tr>
<tr><td>Funding Method:
Competitive</td><td>Funding Mechanism:
Grant</td><td>No. of Initial Passing Applicants/ Bidders:
19 out of 21 bidders</td><td>Rank of Selected Applicant/ Bidder:
Group 1: Ranked # 2</td></tr>
<tr><td colspan="4">If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.</td></tr>
<tr><td colspan="4">Treatment of Intellectual Property:
Pre-existing intellectual property identified in agreement EPC-15-074 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

Subcontractor Conectric, LLC. will employ patented and unregistered IP in the operation of control systems being used to evaluate different load management strategies and customer impacts in this project.</td></tr>
<tr><td colspan="4">Update:
The project is on schedule. Agreements with Solar City (recently acquired by Tesla) to engage and operate the K-12 school sites equipped with solar PV, storage, and load management control capabilities have been finalized and market participation is underway. Installation of monitoring and control equipment at the hotel sites has been completed and audits, data collection, and operational testing are already yielding recommendations for efficiency improvements. The data are being analyzed for the purpose of developing effective DR strategies. Recently, the project expanded participation to the new CAISO ancillary services market.</td></tr>
</table>

EPC-15-083

Project Name: Empowering Proactive Consumers to Participate in Demand Response Programs [EPC-15-083]	
Recipient/Contractor: OhmConnect, Inc.	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 5/18/2016 to 6/28/2019
Program Area and Strategic Objective: Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: The market for third-party demand response (DR) is constrained, severely limiting non-utility resources from contributing to the electricity grid. Although a bi-directional grid is now technically possible, neither prosumers (customers who both draw from and contribute to the grid) nor their devices can be integrated into the energy markets. A chicken and egg situation exists where policymakers and regulators will not open up the market for non-utility energy sources, citing a lack of customer interest, while customers remain unaware of how to contribute to the grid.	
Project Description: This project contains three elements to provide data for policymakers and businesses to explore this new market. First, this project determines prosumer (producer/consumer) interest in a third-party demand response market by testing user acquisition via direct and non-direct engagement strategies. Second, experimentation with behavioral and automated users allows analysis of user yield under a variety of conditions and extract a set of shadow curves that can inform how much energy load shifting can be expected under various price incentives. Finally, this project creates a novel solution for using residential telemetry to connect prosumers and their Internet of Things (IoT) devices to the market operators.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project is providing critical evidence that residential customers are willing to manage their electric loads for the purpose on meeting grid needs when presented with the meaningful, actionable information and salient incentives. The approach makes use of multiple social media platforms for communication and has developed multiple virtual customer "experience" opportunities using those platforms that enhance participation and keep customers interested and involved. The project provides conclusive evidence that with	

the appropriate approach, residential customers can and will adapt their energy use to a grid that depends heavily on variable renewable generation. This evidence can be used to help policymakers and regulators develop more effective direction for utility tariff and program design as well as program parameters for third party aggregator participation in demand response.	
CPUC Proceedings addressing issues related to this EPIC project: Smart grid: R.08-12-009 [closed] Customer Data Access Program: Applications A.12-03-002, 003, 004. Decisions D.11 Distribution Level Interconnection (Rule 21): R.11-09-011 [closed] Demand Response (DR): R.13-09-011 Net energy metering: R.14-07-002 California Solar Initiative: R.12-11-005 Integration of Distributed Energy Resources (IDER): R. 14-10-003 Integrated Resource Planning and Long-Term Procurement Proceeding. LTPP (2016) cycle: R.16-02-007: R.16-02-007 Energy Efficiency Strategic Plan update and action plans: EE Strategic Plan docs	
Applicable Metrics: CPUC Metrics- 1c, 1d, 1e, 1f, 1g, 1h, 3e Lower Costs: This project could reduce electricity costs for participants, permanently reduce the economic overhead associated with interfacing with new grid edge technologies, reduce peak demand on California's energy generation facilities, avoid peak demand energy costs, and provide crowdsourced grid services to meet increased demand, rather than relying on construction of new fossil generators. Greater Reliability: This project could reduce the complexity for grid-edge resources such as renewables and storage to be grid assets, thereby increasing the pool of accessible grid resources, stabilizing the grid by more effectively coordinating demand and supply resources, and enabling grid services to be crowdsourced to balance increased demand.	
Assignment to Value Chain: Demand-side Management	**Total Budgeted Project Admin and Overhead Costs:** $33,903
EPIC Funds Encumbered: $3,995,028	**EPIC Funds Spent:** $2,738,155
Match Partner and Funding Split: Schneider Electric USA Inc.: $120,000 (2.0 %) Honeywell, Inc.: $164,000 (2.8 %) OhmConnect, Inc.: $1,593,378 (27.1 %)	**Match Funding:** $1,877,378
Leverage Contributors: **N/A**	**Leveraged Funds:** $0

Funding Method:	Funding Mechanism:	No. of Initial Passing Applicants/ Bidders:	Rank of Selected Applicant/ Bidder:
Competitive	Grant	19 out of 21 bidders	Group 1: Ranked # 3

If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.

Treatment of Intellectual Property:

Pre-existing intellectual property identified in agreement EPC-15-083 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

OhmConnect has built a user experience when registering, engaging, and interacting with the OhmConnect product. This user experience will be modified in ways to incorporate this project's goals for a subset of users. Those modifications are not covered in this Intellectual Property. During this project, certain portions of this user experience will be exposed in various contexts to the CEC.

Update:

This project is on track. Over 450,000 utility customers have signed up with OhmConnect, and about 35,000 of those participated in the experimental treatments conducted under the EPIC grant. The recipient completed the work to incorporate numerous different transactive signals, including the utility, the CAISO, and EPRI. ">The recipient has completed the preliminary data modeling and has been successfully bidding into and winning contracts to provide DR to the CAISO when dispatched through the Demand Response Auction Mechanism. The draft final report is anticipated in December 2018 and the project is on track for completion in the first quarter of 2019.

EPC-15-075

Project Name: Customer-centric Demand Management using Load Aggregation and Data Analytics [EPC-15-075]	
Recipient/Contractor: Electric Power Research Institute, Inc.	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 5/18/2016 to 12/31/2019
Program Area and Strategic Objective: Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: Load management in buildings has been lagging for decades due to lack of technology that can reliably provide reductions while gaining customer acceptance. As the State moves toward high penetration of customer-sited renewables that increase the management challenges for grid operators, it is imperative that load management for large numbers of small customers become mainstream. The technologies to manage loads are rapidly being developed and deployed, but relying on privately-developed proprietary solutions carries the risk of inconsistent performance as well as customer confusion and dissatisfaction.	
Project Description: This project demonstrates how a large number of small electric loads, each impacted by and tuned to individual customer preferences can provide load management for both utilities and the California Independent System Operator (California ISO). The primary goal is to refine and demonstrate an open-source end-use management platform capable of operating reliably with all or most available end-use devices and thus defining a viable standard protocol to which all vendors can develop new products. The recipient works with an extensive spectrum of leading product providers covering all major distributed energy resources (DERs), such as Nest (thermostats), ThinkEco (plug loads), Honda and BMW (Vehicle Grid Integration), EGuana (smart Inverter) and Ice Energy (Thermal Storage). A variety of price signals are being tested for Time-of-Use customers such as Critical Peak Pricing and Demand Rate. The project is using deep analytics to evaluate individual customer preferences for demand management using microdata from devices and aggregate the responses to meet grid needs at different distribution and transmission levels.	

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project is using low cost off-the-shelf technologies to develop a platform that can manage customer end-use devices according to their preferences, minimize their energy costs, and adapt to evolving tariff structures. By making the task of automating multiple enduse devices easier, less costly, and less of an imposition on customers, the project has the potential to increase demand response participation, with consequent benefits to the electric grid.

CPUC Proceedings addressing issues related to this EPIC project:

Self-Generation Incentive Program: R.12-11-005 Energy storage: R.15-03-011 [Closed] Smart grid: R.08-12-009 [closed] Distribution Level Interconnection (Rule 21): R.11-09-011 [closed] Demand Response (DR): R.13-09-011 Integration of Distributed Energy Resources (IDER): R. 14-10-003 Long-Term Procurement Proceeding (LTPP): R.13-12-010 [Closed] Energy Efficiency Strategic Plan update and action plans: EE Strategic Plan docs Energy Efficiency Proceedings: R.13-11-005, R. 12-01-005, R.09-11-014 [Closed]

Applicable Metrics: CPUC Metrics- 1c, 1d, 1e, 1f, 1g, 1h, 5c Lower Costs:

Benefits include statewide residential electricity savings of approximately 1040 GWh per year and small commercial savings of 53 GWh per year for a total of 1093 GWh per year, which translates to estimated statewide CO_2e reductions of 397,631 metric tons per year. The total annual bill reduction is approximately $8.21M for commercial facilities and $185M for residential buildings.

Greater Reliability:

The project has the potential to increase adoption of demand response programs from the current 15 percent to as much as 60 percent. Managing air-conditioning loads, plug loads, and electric vehicles could provide up to 12 GW of capacity that could be shifted to maximize utilization of renewable resources, provide ramping and other ancillary services, and contribute to greater grid flexibility.

Assignment to Value Chain: Demand-side Management	**Total Budgeted Project Admin and Overhead Costs:** $1,163,894
EPIC Funds Encumbered: $3,998,587	**EPIC Funds Spent:** $1,391,198
Match Partner and Funding Split: Electric Power Research Institute, Inc.: $979,860 (18.6 %) InTech Energy, Inc.: $280,452 (5.3 %) Pedagogy World, Inc.: $10,000 (0.2 %)	**Match Funding:** $1,270,312
Leverage Contributors: **N/A**	**Leveraged Funds:** $0

Funding Method: Competitive	**Funding Mechanism:** Grant	**No. of Initial Passing Applicants/ Bidders:** 19 out of 21 bidders	**Rank of Selected Applicant/ Bidder:** Group 2: Ranked # 1

If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.

Treatment of Intellectual Property:

Pre-existing intellectual property identified in agreement EPC-15-075 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

"Energy360 Power Monitoring, Analytics & Controls" software is pre-existing intellectual property trademarked by InTech Energy.

The Chai Energy Logo is trademarked project-relevant pre-existing intellectual property.

The Olivine DER Platform and the EPRI Smart Thermostat Collaborative Data are projectrelevant, unregistered pre-existing intellectual property.

Update:

The project is on track. The team is working with their key development partners to leverage the demand response scheduling interface with the CAISO market. The recipient continues to make progress on development of their energy information database and customer user interface requirements and testing and refining the messaging across all platforms.

EPC-15-077

Project Name:
Huntington Beach Advanced Energy Community Blueprint [EPC-15-077]

Recipient/Contractor:
The Regents of the University of California, on behalf of the Irvine campus

Investment Plan:	Project Term:
2012-2014 Triennial Investment Plan	6/15/2016 to 7/31/2018

Program Area and Strategic Objective:
Market Facilitation S16: Collaborate With Local Jurisdictions and Stakeholder Groups in IOU Territories to Establish Strategies for Enhancing Current Regulatory Assistance and Permit Streamlining Efforts That Facilitate Coordinated Investments and Widespread Deployment of Clean Energy Infrastructure

Issue:
Electrical utilities face challenges with aging infrastructure and load capacity constraints that limit where certain technologies can be installed. Disadvantaged communities face their own set of challenges that often prevent their clean energy needs from being met. While integrated, community-scale systems that combine local renewable energy sources, energy storage, and control technologies could provide benefits to help the utility and community, new tools and approaches are needed to design these systems in a manner that meets the needs of both groups.

Project Description:
This project designed an integrated energy system to transform the disadvantaged Huntington Beach community of Oak View, into an advanced energy community (AEC). The team worked closely with ComUNIDAD, a community organization, to ensure the community needs were factored into modeling scenarios. The project team developed new design tools to simulate an integrated energy infrastructure on a community-scale, expanding the capability from the existing single-building design tools. The team evaluated multiple scenarios to determine the most optimal set of clean energy technologies and business and financial models to align the community's energy needs within the constraints of the existing electricity infrastructure.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:
Senate Bill 350 (2015) sets a 50 percent renewable energy standard and a goal of doubling energy efficiency savings by 2030. Local governments can play a critical role in achieving this goal by helping facilitate community-scale deployment of Integrated Distributed Energy

Resources (IDER) such as energy efficiency, onsite renewables, demand response, and electric vehicles. This project piloted innovative planning, permitting, and financing approaches and tools to help improve the business case for IDER adoption at the community-scale.

CPUC Proceedings addressing issues related to this EPIC project: Distribution Resources Plans (AB 327): R.14-08-013 Integration of Distributed Energy Resources (IDER): R. 14-10-003	
Applicable Metrics: CPUC Metrics- 2a, 3b, 3e Lower Costs: This tools and approaches piloted in this project will reduce the time and costs needed to design future community-scale IDER projects. Economic Development: This project piloted new approaches and develop new planning tools that can increase the financial attractiveness and overcome some of the common obstacles of deploying communityscale IDER projects, especially in disadvantaged communities. Combined, these can lead to increased investment energy savings and investment in the community. Consumer Appeal: Greater deployment of advanced energy technologies at a community scale will increase consumer familiarity and comfort with Zero Net Energy homes and communities. This will increase the likelihood of consumers choosing to live in communities deploying advanced energy technologies.	
Assignment to Value Chain: Demand-side Management	**Total Budgeted Project Admin and Overhead Costs:** $508,226
EPIC Funds Encumbered: $1,500,000	**EPIC Funds Spent:** $337,423
Match Partner and Funding Split: Southern California Edison: $200,000 (8.7 %) County of Orange/City of Huntington Beach: $152,900 (6.6 %) Altura Associates, Inc.: $62,000 (2.7 %) National Renewable Energy Laboratory (NREL): $200,000 (8.7 %) Southern California Gas Company	**Match Funding:** $810,998

(SoCalGas): $150,000 (6.5 %) The Regents of the University of California, Irvine Advanced Power and Energy Program: $46,098 (2.0 %)			
Leverage Contributors: **N/A**		**Leveraged Funds:** $0	
Funding Method: Competitive	**Funding Mechanism:** Grant	**No. of Initial Passing Applicants/ Bidders:** 27 out of 28 bidders	**Rank of Selected Applicant/ Bidder:** Group 4: Ranked # 4
If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.			
Treatment of Intellectual Property: Pre-existing intellectual property identified in agreement EPC-15-077 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.			
Update: The project ended in July 2018. Using the UrbanOpt and DEROpt tools to determine the most optimal technical and economical suite of clean energy technologies, the team developed a master community design for the Oak View AEC. Because of the mild climate and limitations with aging building stock, the plan consists of the most impactful energy efficiency upgrades (lighting and plug-loads), as well as community-scale solar PV systems mounted on carports and rooftops, and energy storage. These systems were sized to reduce the overall electrical use by the maximum of nearly 94 percent. Finally, to encourage community acceptance, the team offered a ten-week STEM course to the elementary school's after-school program, and held a series of workshops to introduce residents to green energy concepts providing materials in Spanish and playing games familiar to the predominantly Hispanic community.			

Project Name: Complete and Low Cost Retail Automated Transactive Energy System (RATES) [EPC-15-054]	
Recipient/Contractor: Universal Devices, Inc.	
Investment Plan: 2012-2014 Triennial Investment Plan	**Project Term:** 6/30/2016 to 3/29/2019
Program Area and Strategic Objective: Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue: Existing Demand Response programs, tariffs and wholesale markets in California are focused primarily on reliability and peak load reduction. The end-use loads enrolled in these programs tend to have high opportunity costs so participation in these programs is low. Participation logistics - including metering, telemetry, baseline estimation, verification and settlement - still serve as a barrier to wider participation. Substantial research and technology development over the past decade have pointed toward a vast untapped potential for balancing electricity supply and demand in near-real time through better management of customer loads and distributed energy assets.	
Project Description: This project will develop and pilot-test a standards-based Retail Automated Transactive Energy System (RATES), and behind the meter energy management solution. The purpose is to minimize the cost and complexity of customer participation in energy efficiency programs, maximize the potential of small loads to improve system load factor, shave peaks, integrate renewable generation, and provide low opportunity-cost resources to the grid. This project will work with Southern California Edison to facilitate customer participation and expand Demand Response Participation in the area served the Moorpark substation.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project is developing an energy management automation platform that will allow customers to participate in Demand Response (DR) markets by providing them the means to pre-program their preferred operational settings for end-use devices such as thermostats, pool pumps, and battery storage under variable pricing conditions. The technology is	

applying those preferences to automating real-time response to energy market and rate variations using off-the-shelf equipment and a two-way subscription tariff design that allows customers to consume when prices are low and conserve when prices are high, without the need for complicated measurement, verification, and baselines. This technology will reduce barriers to low cost, anytime responsiveness from millions of customers and their devices by solving the significant cost and complexity of current DR participation options.	
CPUC Proceedings addressing issues related to this EPIC project: Demand Response (DR): R.13-09-011 Resource Adequacy (RA) 2016 and 2017 Compliance Years: R.14-10-010 [Closed] Integration of Distributed Energy Resources (IDER): R. 14-10003	
Applicable Metrics: CPUC Metrics- 1c, 1e, 1f, 1g, 1h, 3f, 4a Lower Costs: The primary goal of the project is to reduce the cost of customer participation in energy efficiency and automated demand response programs. Expanded participation will lower ratepayer costs by reducing procurement and grid capacity expansion costs as well as reducing carbon emissions and helping integrate renewables. Greater Reliability: Greater resiliency of demand will increase reliability as additional variable renewable generation resources are added to the grid. Variable renewables require procurement of additional "firming" resources to provide both ancillary services and generation resources when renewable production drops. Successful expansion of the ability of loads to respond to supply variation allows grid operators an additional tool to balance demand and supply.	
Assignment to Value Chain: Demand-side Management	**Total Budgeted Projec t Admin and Overhead Costs:** $0
EPIC Funds Encumbered: $3,187,370	**EPIC Funds Spent:** $2,493,558
Match Partner and Funding Split: TeMix, Inc.: $919,325 (21.5 %) TBD Electrical Contractor: $7,000 (0.2 %) TBD - Controls: $1,150 (0.0 %) Universal Devices, Inc.: $160,235 (3.7 %)	**Match Funding:** $1,087,710
Leverage Contributors: **N/A**	**Leveraged Funds:** $0

Funding Method:	Funding Mechanism:	No. of Initial Passing Applicants/ Bidders:	Rank of Selected Applicant/ Bidder:
Competitive	Grant	19 out of 21 bidders	Group 2: Ranked # 4

If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.

Treatment of Intellectual Property:

Pre-existing intellectual property identified in agreement EPC-15-054 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.

Update:

The project is on schedule, required deliverables have been provided, and the level of engagement by utilities and other partners is expanding the project impacts beyond what was initially anticipated in the agreement. SCE has provided additional funding to support expansion of the research in the Moorpark substation area (a Disadvantaged Community also at risk for reliability issues). In addition, Google has been working with the team to evaluate its Alexa technology as a platform for hosting the transactive client. Demonstrations are underway and SCE has provided funding to expand the number of test sites and include battery storage in the pilot, as well as facilitating expanded participation in CAISO markets by developing and getting CPUC approval for an experimental tariff tailored to this project. The final report is anticipated January 10, 2019.

EPC-15-073

Project Name:	
Identifying Effective Demand Response Program Designs to Increase Residential Customer Participation [EPC-15-073]	
Recipient/Contractor:	
The Regents of the University of California, on behalf of the Los Angeles Campus	
Investment Plan: Project Term:	
2012-2014 Triennial Investment Plan	6/30/2016 to 3/31/2019
Program Area and Strategic Objective:	
Applied Research and Development S2: Develop New Technologies and Applications that Enable Cost-Beneficial Customer-sideofthe-Meter Energy Choices	
Issue:	
As the state moves toward more distributed generation and intermittent renewable energy generation, there is a need for smaller resources to play larger roles in distribution and transmission grid management. The end-use loads enrolled in Existing Demand Response (DR) programs have high opportunity costs and participation is low. Some newly-developed market options, such as aggregation programs, could enable large numbers of small loads across multiple customers to participate in wholesale markets. However, participation logistics, including metering, verification and settlement, are barriers to wider participation.	
Project Description:	
This project is testing the effectiveness of innovative designs for demand response programs for residential customers using a behind-the-meter customer engagement platform developed by OhmConnect. Each of these innovative demand response strategies integrates a recent approach that energy researchers have shown to be effective in reducing customer consumption. These strategies include providing households with a) tailored energy-analytic feedback, b) aggregated versus single-period incentive information, c) non-financial environmental health benefit frames and d) social comparisons. An additional strategy is exploring how the timing of the delivered demand response information affects the magnitude of household participation and response.	
How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:	
This project will test the effectiveness of innovative design strategies for residential demand response providers and analyze different segments of the residential population including various socioeconomic groups and residential customers with photovoltaics and electric vehicles to see what incentives, messages and energy use information motivates reliable	

participation in utility demand response programs. This information will expand knowledge in this area so that utility companies and regulators can build new and modify existing demand response programs to increase effectiveness. Accurate and reliable forecasts of participation in these programs will enable better utilization of existing generation resources and deferral of system capacity upgrades thereby lowering consumer electricity costs.	
CPUC Proceedings addressing issues related to this EPIC project: Demand Response (DR): R.13-09-011	
Applicable Metrics: CPUC Metrics- 1c, 1d, 1e, 1h Lower Costs: This project could lower ratepayer costs through better utilization of existing electricity generation resources by having residential customers participate in demand response (DR) programs. System-wide this could reduce the need for high cost peaker plants during extreme climate events. Participants in the DR programs could be rewarded with incentives that would result in lower energy bills. One of the project goals is to learn what potential demand reduction could be achieved by optimizing the metrics of residential DR programs. Greater Reliability: Greater electric system reliability could be achieved through increased residential demand response program participation and having this contribute towards greater grid optimization, flexibility and lowering imbalances on the grid.	
Assignment to Value Chain: Demand-side Management	**Total Budgeted Project Admin and Overhead Costs:** $203,115
EPIC Funds Encumbered: $2,007,875	**EPIC Funds Spent:** $1,136,736
Match Partner and Funding Split: Chai Energy: $288,853 (11.2 %) University of California Los Angeles: $273,780 (10.7 %)	**Match Funding:** $562,633

Leverage Contributors: **N/A**		**Leveraged Funds:** $0	
Funding Method: Mechanism: Competitive Grant	**Funding**	**No. of Initial Passing Applicants/ Bidders:** 19 out of 21 bidders 5	**Rank of Selected Applicant/ Bidder:** Group 2: Ranked #
If not the highest scoring applicant/bidder, explain why selected: Funds were awarded to passing proposals in rank order.			

Treatment of Intellectual Property:
Pre-existing intellectual property identified in agreement EPC-15-073 (Confidential Products and Pre-Existing Intellectual Property Lists, Attachment C-2) will reside with the recipient. New intellectual property developed under this agreement will be subject to the agreement Terms and Conditions.
Update:
UCLA is working with its subcontractor, Ohm Connect, to analyze the effects of nonlinear incentives and baseline on customers and how it impacts their willingness to participate in Demand Response (DR) events. Nonlinear incentives are monetary rewards which increase exponentially with participation in DR events. The preliminary results are inconclusive which means that the data needs to be further refined with different variables. In addition, the analysis has shown that as the customer's baseline increases by 1 kWh there is an average of 0.2 kWh increase in their energy consumption during a DR event. This means customers would be more inclined to consume energy if they are given a large baseline because they would be able to get the incentive and still consume energy.

APPENDIX B: Technical Advisory Committee and Technical Advisory Board Members and Organizations

The list below shows the project Technical Advisory Committee and Board members.

Technical Advisory Committee

- Alternative Energy Systems Consulting (AESC), Mike Ferry
- BMW North America, LLC, Adam Langton
- California Energy Commission (CEC), David Hungerford (Project Manager)
- California Institute of Energy and Environment (CIEE), Carl Blumstein
- Center for Sustainable Energy (CSE), Pierre Bull
- Electric Power Research Institute (EPRI), Sunil Chhaya
- Institute of Electrical and Electronics Engineers (IEEE), Bob Heile (IEEE 2030.5 WG)
- IEEE 2030.5 Standard (Smart Energy Profile 2.0), Robby Simpson (Test and Certify)
- OhmConnect, John Anderson
- OpenADR Alliance (OpenADR 2.0 Standard), Barry Haaser
- Organization for Advancement of Structured Information Standards (OASIS), Laurent Liscia
- Smart Grid Interoperability Panel/ Smart Electricity Power Alliance (SEPA), Dave Hardin
- Universal Devices/ TeMIX, Ed Cazalet
- University of California Los Angeles (UCLA) Luskin Center, Julien Gattaciecca

Technical Advisory Board

- California Energy Commission (CEC), David Hungerford (CAM)
- California Independent System Operator (CAISO), Jill Powers
- California Public Utilities Commission (CPUC), Cathleen Fogel
- Lawrence Berkeley National Laboratory (LBNL), Mary Ann Piette
- National Institute of Standards and Technology (NIST), David Holmberg
- Pacific Gas & Electric Company (PG&E), Abigail Tinker
- Pacific Northwest National Laboratory, GridWise Architecture Council, Steve Widergren
- Sacramento Municipal Utility District (SMUD), Denver Hinds
- San Diego Gas and Electric (SDG&E), Tony Rafati
- Southern California Edison (SCE), Mark Martinez
- US Department of Energy (DOE), Chris Irwin

APPENDIX C: Demand Response Symposium Participating Members and Organizations

The table list below shows the participating members for the DR Symposium hosted by the project in July 2019.

Table C-1: Participating Members for Demand Response Symposium

First Name	Last Name	Company
John	Clint	Alternative Energy Sys. Consulting, Inc.
Stephen	Barrager	Baker Street Publishing, LLC
Adam	Langton	BMW of North America, LLC
Matthew	Fung	California Energy Commission
David	Hungerford	California Energy Commission
Nick	Janusch	California Energy Commission
Pat	McAuliffe	California Energy Commission
Gabriel	Taylor	California Energy Commission
Jackson	Thach	California Energy Commission
Peter	Klauer	California ISO
Jill	Powers	California ISO
Aloke	Gupta	California Public Utilities Commission
Jean	Lamming	California Public Utilities Commission
Pierre	Bull	Center for Sustainable Energy
Ammi	Amarnath	Electric Power Research Institute (EPRI)
Sunil	Chhaya	Electric Power Research Institute (EPRI)
Andrew	Coleman	Electric Power Research Institute (EPRI)
Benjamin	Ealey	Electric Power Research Institute (EPRI)
Girish	Ghatikar	Electric Power Research Institute (EPRI)
Haresh	Kamath	Electric Power Research Institute (EPRI)
Ramachandran	Narayanamurthy	Electric Power Research Institute (EPRI)
Nicholas	Tumilowicz	Electric Power Research Institute (EPRI)
Alekhya	Vaddiraj	Electric Power Research Institute (EPRI)
Donald	Von Dollen	Electric Power Research Institute (EPRI)
Matthew	Wakefield	Electric Power Research Institute (EPRI)
Walt	Johnson	IEEE-SA
Stephan	Barsun	ITRON, Inc.
Jean	Shelton	ITRON, Inc.
Mary	Piette	Lawrence Berkeley Laboratory
Matt	Duesterberg	OhmConnect, Inc.

First Name	Last Name	Company
Lillian	Mirviss	OhmConnect, Inc.
Rolf	Bienert	OpenADR Alliance
John	Hernandez	Pacific Gas & Electric Co.
Arvind	Simhadri	Pacific Gas & Electric Co.
Deepak	Aswani	Sacramento Municipal Util. Dist.
Denver	Hinds	Sacramento Municipal Util. Dist.
Nicholas	Connell	Southern California Edison Co.
Mark	Martinez	Southern California Edison Co.
Liang	Min	Stanford University
Venkat	Prabhala	SunSpec Alliance
Thomas	Tansy	SunSpec Alliance
Edward	Cazalet	TeMix Inc.
Therese	Peffer	U.C. Berkeley
Ben	Finkelor	UC Davis Energy Institute
Orly	Hasidim	Universal Devices, Inc.
Julien	Gattaciecca	University of California
Frances	Cleveland	Xanthus Consulting International

Source: EPRI

APPENDIX D:
Demand Response Symposium Survey Questions

The document below shows the survey questions that were distributed to the DR Symposium attendees.

Transactive Load Management (TLM) Signals Survey

(Circle or underline your answers)

Full Name: ....

Organization: ....

Contact (E-mail and/or Phone): ....

1. Based on the research findings, *how effective* are the TLM signals in increasing demand response from DERs in the California grid?
   a) Very Effective
   b) Somewhat Effective
   c) Not effective
   d) I have a different perspective (explained below).

Explain:...

2. Based on the research findings, *how reliable* are the TLM signals to manage integrated DR from optimized **supply**-side load resources (Group 1 projects)?
   a) Very Reliable
   b) Somewhat Reliable
   c) Not Reliable
   d) I have a different perspective (explained below).

Explain:...

3. Based on the research findings, *how reliable* are the TLM signals to manage integrated DR from optimized **demand**-side load resources (Group 2 projects)?

a) Very Reliable
b) Somewhat Reliable
c) Not Reliable
d) I have a different perspective (explained below).

Explain:………
………………………………………..

4. What *research would you recommend* for advancing mainstream TLM-based signals and a TIME-like system to elicit DR?
   a) Enough research has been done to prove TLM Signal effectiveness
   b) More research is needed to understand the effectiveness of TLM Signals
   c) Better understanding of the economics for TLM signals is needed
   d) More research is needed to prove the value to the consumer
   e) More research is needed to prove the value to the Grid
   f) Something else (explained below).

Explain:………
………………………………………..

5. What, in your opinion, must California stakeholders do to *mainstream* TLM-centric business models?
   a) Utilities and ISO must operationalize TLM Research findings in their business models
   b) Regulatory support will be needed to realize the societal benefits of the TLM signal
   c) Focused applied research and field testing will be needed before the business value can be determined
   d) Technology vendors must offer innovative solutions to increase the reliability of DR in supply and demand-side markets
   e) Something else (explained below).

Explain:………
………………………………………..

6. *How important* are interoperability standards have in energy systems integration using a TLM-centric approach?
    a) Important
    b) Somewhat important
    c) Not important
    d) I have a different perspective (explained below).

Explain:...
....**..**

7. *How important* is it to design a system that leverages advanced methods and analytics to combine real-time system information with forecasts of loads (demand) and distributed generation (DG) production?[8]
    e) Important
    f) Somewhat important
    g) Not important
    h) I have a different perspective (explained below).

Explain:...
....**..**

Return your survey answers to Rish Ghatikar (GGhatikar@epri.com)

---

[8]The research used California ISO DAM Pnode LMPs for supply-side, and simple globally adjusted California ISO DAM DLAP prices for demand-side TLM prices.