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ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Complete and Low-Cost Retail Automated Transactive Energy System (RATES)

Gavin Newsom, Governor

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California Public Utility Commission (CPUC): The CPUC provided feedback to the RATES team in presentations at various phases of the pilot. Their feedback and comments were used by the RATES team to improve the pilot. CPUC representatives reviewed, processed, and accepted the advice letter filed by SCE for the experimental subscription transactive tariff used in this project.

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TeMix Inc.: TeMix is a leading provider of transactive systems and services to the power and energy industry. The major TeMix contributors on the project were:

- Dr. Edward Cazalet, RATES principal investigator, transactive energy methodology and RATES system design.
- Dr. Bo Mi, TeMix Platform™ and TeMix Portal.
- Robin Mi, subscription tariff implementation and interfaces to the distribution operator, load-serving entity and California ISO.

- Dr. Steve Barrager, TeMix Agent™ machine learning, and optimization algorithms design.
- Hang Zhou, TeMix Agent interfaces.
- Dr. Greg Sigalov, device agent optimizers and machine learning.
- Ron Pasquarelli, Green Button meter data system interface.

Universal Devices Inc.: Universal Devices (UD) is a leading manufacturer of affordable, internet-accessible, home automation, energy management, and conservation products and solutions. The major UD contributors on the project were:

- Michel Kohanim, design and management of installation and operation of customer-facing RATES hardware and software.
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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.

Complete and Low-Cost Retail Automated Transactive Energy System (RATES) is the final report for Contract Number EPC-15-054 conducted by Universal Devices Inc. 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 916-327-1551.

ABSTRACT

This research project demonstrated a transactive energy system for a retail decentralized energy market interfaced with customers, a distribution operator, a load-serving entity, and a wholesale market. The Retail Automated Transactive Energy System (RATES) platform hosts a subscription transactive tariff with dynamically priced offers and transactions to help customers automate and self-manage their energy usage and generation. The tariff also uses electricity subscriptions to protect customers and suppliers from volatile bills, fairly allocate costs among customer classes, and support investments in clean generation, storage, and energy efficiency.

The RATES platform manages electricity transactions with binding terms for physical delivery and payment between Southern California Edison and each participant. The spot prices (current energy tariff prices) sent to customers include wholesale spot energy prices plus scarcity-based dynamic price adders, and dynamic distribution prices for each distribution circuit.

With the support of Southern California Edison, the RATES team developed and received California Public Utilities Commission approval for the experimental subscription transactive tariff. For each of 115 Southern California Edison participants, the project team installed an ISY994 Series Internet of Things (IoT) and smart-grid-based energy management system, communicating thermostat, Alexa voice assistant, and a pool controller where possible. Optimizing agents were developed to assist customer self-management of device operation. All systems were available for more than a year of continuous, real-time, end-to-end development and testing of RATES.

The research demonstrated the feasibility of RATES in actual operation. Lessons learned are documented. Alternatives for further research and wide installation of the subscription transactive tariff and the platform are developed, as well as preliminary estimates of the costs and qualitative estimates of the benefits to ratepayers.

Keywords: transactive energy, electricity subscriptions, IoT, smart grid, energy management, energy efficiency

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EXECUTIVE SUMMARY

Background

California has an aggressive policy (Senate Bill 100 [Author, Chapter, Statutes]) directing that renewable and zero-carbon energy resources will supply 100 percent of all retail electricity sales by December 31, 2045. Senate Bill 350 (Author, Chapter, Statutes) increases energy efficiency and electrification of buildings and transportation to reduce carbon emissions. The result is rapidly increasing variable renewable solar and wind generation, with decentralized ownership and location and increased electrical demand.

California ratepayers (customers) generally do not yet have any automated means and signals to help them use more electricity to heat or cool, charge their electric vehicles and storage, pump water, and use appliances when clean, renewable electricity is abundant and cheap, and use less when it is scarce, expensive, and less clean.

It is difficult and expensive to achieve California's clean energy goals without automated systems, a dynamic price tariff, and a transaction system to support customer self-management of their electricity use.

Customer self-management of electricity must be coordinated with other retail and wholesale generation and use, hour-by-hour and minute-by-minute throughout the day. This coordination challenge is increasingly difficult, with more distributed generation and storage, more community choice aggregators (CCAs), and more microgrids required for forest fire resiliency.

Two approaches are currently being attempted in California for this coordination:

- A supply-side approach, where retail customers contract with aggregators to offer their demand response, retail generation, and storage to an aggregator to be sent or dispatched as a virtual power plant by the California Independent System Operator (California ISO).
- A demand-side approach, using time-of-use retail tariffs with typically three different prices for blocks of time during each day.

The supply-side approach is complex and unable to completely capture the full customer use, distribution, retail energy, and wholesale transmission and energy benefits. And, many customers do not want to turn over control of their electrical devices to aggregators, or to the California ISO, thus limiting participation.

The time-of-use retail tariff, demand-side approach cannot provide the necessary price variability to cover the full range of prices, from negative to thousands of dollars per Megawatt-hour.

One demand-side solution for a real-time retail price is the California ISO wholesale real-time price plus a fixed retail adder. However, the wholesale real-time price variability is modest, and a fixed retail adder likely would not provide a sufficiently variable and locational price signal for distributed storage, electric vehicle charging, and heating, ventilation, and air conditioning (HVAC) operation.

Pure retail real-time pricing raises resource adequacy concerns if the result is reduced investment in resources. Measuring the contributions of renewable generation and batteries is difficult because the definition of capacity used is typically fixed over time. Such pricing also raises market and grid stability concerns, including potential overresponse to a large price change, as well as customer bill and utility revenue volatility.

Finally, the operation of devices to shift and shape usage to increase the use of midday solar generation and reduce evening fossil generation requires real-time hourly and sub-hourly prices, and hourly prices for at least the next 24 hours, with prices often changing during the day as weather and supply and demand change.

For nearly two decades in California, progress toward retail real-time pricing has stalled. Advances in information technology, Internet of Things (IoT), and low-cost off-the-shelf smart devices currently being used by customers for convenience, entertainment, and security can now be leveraged for automated and optimized management of electricity use in response to real-time and other dynamic retail electricity prices.

No single vendor, utility, or agency has been able to implement a solution. Hence, ratepayer support is required to fund the research that no one entity has the scope or funds to support.

Project Purpose

The purpose of the project is a proof-of-concept demonstration of a demand-side solution to the challenges and research gaps described above, which the team calls the Retail Automated Transactive Energy System (RATES). The team's goal was to prove the RATES concept with ratepayers and their devices, interfaces to Southern California Edison (SCE) and the California Independent System Operator (California ISO), a subscription transactive tariff approved by SCE and the California Public Utilities Commission (CPUC), and actual tenders and transactions.

The proposed solution includes an innovative retail tariff with real-time, actionable prices and bill stability. The solution also offers a platform to communicate the price offers (buy and sell tenders) to customers so that operation of their electrical devices can be automated for their benefit. The platform interfaces with SCE and the California ISO, including scheduling, metering, and billing calculations for the tariff. The solution also provides a low-cost, off-the-shelf, and IoT energy management system that interfaces with SCE smart meters, off-the-shelf customer devices, photovoltaics, electric vehicles, and artificial intelligence assistants and controls devices in response to prices, while considering customer comfort and convenience.

Ratepayers or customers should care about this research because it can reduce their cost of electricity as California transitions to its 100 percent clean energy goals, and because RATES promotes leveraging existing and/or low-cost off-the-shelf customer devices. In this way, customers can easily manage all their appliances for convenience, comfort, cost savings, and environmental interests, while using user-friendly voice assistants.

The technical objectives included demonstration of the following:

- An end-to-end RATES with prices from the California ISO, SCE distribution operator, and SCE load-serving entity to customer facilities and devices.

- Low-cost, off-the-shelf end devices that can feed back and sum device kilowatt (kW) usage to the facility, SCE load-serving entity, SCE distribution operator, and the California ISO.
- Use of the subscription transactive tariff, including the development of subscriptions for each customer.
- Calculation of hourly, 15-minute, and 5-minute tender (offer) prices based on the California ISO, SCE distribution operator, and SCE load-serving entity marginal costs.
- Metering of actual facilities, using existing SCE smart meter infrastructure, at 5- or 15-minute granularities and the calculation of customer bills based on the subscription transactive tariff.
- Voice assistants for device management.
- Real-time optimization agents for each device class or category.
- The feasibility of leveraging a low-cost, off-the-shelf, IoT-based energy management system for integrating devices, SCE smart meters, artificial intelligence assistants and, more importantly, with the transactive energy platform.

Project Approach

The team for this project combined the capabilities of Universal Devices, a leading manufacturer of home automation, IoT, and energy management systems with the capabilities of TeMix Inc., a leading provider of transactive energy systems and services. The team also included experts and resources from SCE, the CPUC, the California ISO, and the California Energy Commission (CEC).

In this project, the team completed the design of RATES, and:

- Implemented the RATES design, including the transactive energy platform and the in-home use of an energy device control hub and smart devices.
- Installed RATES in about 100 homes on an SCE distribution circuit.
- Interfaced RATES to the SCE load-serving entity and distribution operator and the California ISO.
- Implemented a subscription transactive tariff and obtained CPUC approval for it as an experimental tariff.
- Adapted the TeMix transactive energy platform to support RATES.
- Adapted Universal Devices' low-cost energy management system and software to support RATES.

The RATES tariff uses a customer-specific subscription quantity (kW) for each hour for a year or more at a fixed monthly cost. (kW denotes the rate of energy flow. One kW for one hour is equivalent to one kilowatt-hour [kWh]. One kW for a day of 24 hours is 24 kWh. One kW for five minutes is 1/12 kWh.)

The customer's historical metered usage determines the hourly subscription quantities, and the current SCE tariff applied to the subscription quantities determines its monthly fixed cost. If the customer uses about the same energy in each hour as subscribed, the customer's bill will be about the same.

Within RATES, load-serving entities and distribution operators, such as SCE, act as "market makers," frequently posting kW quantity, buy and sell tenders (offers) to each retail party. The tenders are based on wholesale market prices plus retail adders that recover other fixed and variable costs at higher prices when the distribution circuit and generation load is high.

RATES' optimization agents and low-cost energy management system work hand-in-hand to automatically adjust usage and generation based on hourly, 15-minute and 5-minute tender prices while taking customers' preferences into consideration. RATES automatically transacts portions of the buy and sell tenders for these intervals so that their planned net usage and generation balances their net purchases in each interval for which tenders are available. To provide customers with the most flexibility, they are not required to respond to tenders with transactions and, therefore, RATES enables considerable flexibility for market designers in the granularity of implementation for different customer sectors.

RATES tariff settlement is straightforward. The monthly bill is the sum of the payments for the transactions in the month, taking account of whether the transaction is a buy or sell transaction. There is no need for overlaying the RATES tariff with demand charges, additional demand response programs, signals, and baseline estimates because customers are already using the correct marginal costs.

After meetings with SCE to ascertain how best to interface with the utility, the team then developed formal requirements for the key components and interfaces to customer devices, SCE customer meters, historical meter data, the California ISO, and weather service. Interfaces were developed for team members to configure the TeMix Platform and Universal Devices' ISY994 series low-cost and off-the-shelf energy management system for RATES, then to register customers and provide real-time systems for monitoring the operation of all systems from the California ISO to devices in the customer facilities, including resulting transactions.

The transactive platform development began with a prototype of the TeMix Platform created by TeMix over several years but not yet put into commercial operation. The platform uses standard protocols for tenders, transactions, positions, and delivery. These standards were developed several years ago for the Smart Grid Interoperability Panel and are found in OASIS, "Energy Market Information Exchange (EMIX) Version 1.0" 2012, and OASIS, "Energy Interoperation Version 1.0" 2014.

Major efforts were expended to harden cybersecurity, support many parties, and provide scalability for a production environment.

Early in the project, the team developed the interface to the California ISO to retrieve locational prices for any transmission substation and particularly SCE's Moorpark substation, where the pilot was conducted. The interfaces between the energy management system and the transactive energy platform were developed to ensure cybersecure receipt of tenders and creation of transactions. For more than 18 months, RATES was operated end-to-end at five-minute granularity, with over 100 participants, and under a wide range of failure and recovery conditions, seasonal conditions, and weather changes.

The TeMix Agent is several software agents each for a type of device: HVAC, pool pump, battery, electric vehicle, and appliances; and uses real-time energy and state information from the smart meter and other sources for optimization. TeMix Agent is platform independent, and therefore it can run locally on the energy management system or independently in the cloud. Extensive design efforts were conducted to model each device and develop mathematical optimization routines that can solve in sub-second times. Machine-learning algorithms were designed, tested, deployed, and iteratively improved to provide parameters to model the thermodynamics of HVAC and the associated facility.

Working with SCE, the RATES team designed, developed, and obtained SCE and CPUC approval for an experimental subscription transactive tariff. The tariff uses scarcity pricing curves to recover the fixed costs of delivery and generation with dynamic prices that are higher when the use of the system is high.

A major effort was made to recruit participants on SCE's Moorpark circuit, including passing out fliers, calling individually, using social media marketing, and going to the city council meetings. The result was 170 candidates, out of which 40 were intimidated by SCE's customer information request (CISR) form or did not have a two-year history and dropped out. Eventually, 115 residences and businesses were recruited to participate in the pilot. At least five customers have a solar system. The team installed for each customer a Universal Devices ISY 994 energy management system, Amazon Alexa voice assistant, and a thermostat. Also installed were 18 pool controllers and three battery storage units.

Project Results

The RATES project achieved what Universal Devices was expecting and met the goals of the EPIC grant. The team demonstrated the feasibility of integrating wholesale and retail market operations using a transactive system.

As importantly, the project showed that low-cost, off-the-shelf, and even existing customer IoT devices, Photovoltaics, and electric vehicles can be leveraged and incorporated into RATES.

Validating the core principles and concepts of RATES has spawned independent projects, including using dynamic variable prices provided by RATES to enable agricultural energy users to efficiently self-manage irrigation scheduling. In addition, SCE is examining an extension of this project to continue research objectives that may not have been addressed in the original scope.

Technology/Knowledge Transfer/Market Adoption

The audience for this research is primarily the California utilities, the CPUC, the CEC, and the California ISO. Another audience for this research is manufacturers, installers, and operators of smart home systems, thermostats, pool pumps, inverters, battery storage, agricultural pumping controls, building energy management systems, and electric vehicle charging systems. A further audience is the energy policy community, including residential, commercial, and industrial advocates, environmental advocates, academic researchers, the Legislature, and the Governor's office.

The near-term market for RATES is SCE and its customers with flexible devices. The next markets would be the other independently operated utilities, CCAs, municipal utilities, and their customers with flexible devices. Finally, RATES can be extended to most California customers, other Western utilities, and customers participating in the California ISO energy imbalance market, as well as other United States and international utilities.

The results of this research provide an operating example of a system of dynamic pricing, with prices designed to capture the full marginal costs of electricity on a highly granular location and time basis. The team demonstrated what is possible, so effective solutions to markets with 100 percent clean energy can now be designed and implemented by the responsible public policy organizations.

Benefits to California

California’s 100 percent clean energy and electrification goals already address emissions; thus, the primary contribution of RATES is to substantially reduce the ratepayer and grid costs of achieving the state’s emission and other goals.

All California independently operated utilities, CCAs, and municipal utilities can develop projects based on RATES, which can be scaled to many millions of customers.

CHAPTER 1: Introduction

Problem Summary

By 2045, the California electricity sector will transition to low-carbon, 100 percent clean electricity that can provide economic benefits and a cleaner environment for all Californians. The transition is toward less electricity generated from using fossil fuels, such as natural gas, to electricity generated using renewable energy sources, such as solar and wind.

In this transition, it makes sense to use more clean electricity for vehicles, mass transportation, and heating buildings that currently use natural gas, which is not 100 percent clean. It is especially important to use more clean energy for transportation and buildings when there is renewable energy overgeneration. Additionally, it makes sense to store electricity from renewable energy sources when it is abundant and use it when it is required to displace more fossil fuel combustion for these purposes.

The renewable energy generation and storage will be at many locations on the grid. Many parties, including electricity customers, will own and operate renewable energy and storage devices, increasing the decentralization of grid management. And the growth of CCAs and microgrids will further increase the decentralization of grid management.

Key Challenges

The challenges associated with rapidly increasing solar electricity generation are well understood, but not yet well managed. As a result of high midday solar generation, midday negative wholesale prices are increasingly frequent. The rapid increase in evening loads as solar generation decreases causes a rise in the demand for other electricity generation or storage. These changes create a challenging wholesale and retail coordination problem to balance electricity supply and demand, hour-by-hour and minute-by-minute throughout the day.

One supply-side approach is a mechanism to allow retail generation, storage, and demand response to participate in wholesale markets operated by the California Independent System Operator (California ISO). In this approach, retail storage and demand response customers and aggregators are challenged to combine revenues for services from wholesale markets with other revenues and to participate in increasingly complex wholesale and retail operational processes. It is complex to implement and often requires aggregators to submit bid curves into the California ISO dispatch markets. There are also challenges in stacking revenue streams from the California ISO, distribution operators, load-serving entities, and end customers.

One demand-side approach uses time-of-use (TOU) retail tariffs that have three different prices for blocks of time during each day. With three fixed periods during the day, TOU price variability cannot cover the full range of the hourly or sub-hourly costs, and the periods of energy surplus or shortage change during the day. Demand response programs are sometimes combined with the tariffs to reduce peak loads, which now occur mostly in the evening. These programs require estimated baselines. It is challenging to create 24/7 baselines for demand response load increases in the middle of the day, and decreases in the evening. This strategy is complex, expensive, and unreliable.

The approach adopted in this project is also a demand-side approach. A decentralized retail market is developed that is hosted on a retail automated transactive energy system interfaced with the California ISO wholesale markets, the SCE distribution operator, the SCE load-serving entity, and end customers and their devices. This project has designed, implemented, and operated such a system at a pilot-scale. The project team calls it the Retail Automated Transactive Energy System (RATES).

Project Goal and Objectives

The overall goal of the project was to:

> *Develop and pilot-test* (proof-of-concept) *a complete, low-cost, and standards-based RATES that maximizes the potential of large numbers of residential and small commercial customers to self-manage their electricity use to save money as California achieves its 100 percent clean energy and electrification goals by 2045.*

Within this goal, the team had several objectives related to the technical gaps and challenges described above. The technical objectives included demonstration of the following:

- An end-to-end RATES with prices from the California ISO, SCE distribution operator, SCE load-serving entity to customer facility, agents, and a control system to manage each controllable device
- End devices that can feed back and sum device kilowatt (kW) usage to the facility, the SCE load-serving entity, the SCE distribution operator, and the California ISO.
- The subscription transactive tariff, including the development of subscriptions for each customer.
- Calculation of hourly, 15-minute, and 5-minute tender (offer) prices based on the California ISO, SCE distribution operator, and SCE load-serving entity (LSE) marginal costs.
- The metering of actual facilities at 5- or 15-minute granularities and the calculation of customer bills based on the subscription transactive tariff.
- Voice assistants for device management.
- Real-time optimization agents for the devices.
- An in-facility control platform for two-way communication with devices, the SCE meter, and the cloud.

CHAPTER 2: Project Approach

Project Team

Universal Devices

Universal Devices is a leading manufacturer of affordable, internet-accessible home automation, energy management, and conservation products and solutions. Universal Devices develops hardware and software solutions that enable automation and energy management. It's hardware is used in demand response programs in several states and by multiple utilities. Universal Devices has an active role in the OpenADR Alliance, is a demand response subject matter expert, and has been one of the key participants in specification development for the Alliance.

Universal Devices is the prime recipient of this grant and oversaw the grant's project management, hardware purchases, hardware installation, most of the customer services/support, and customer-facing software development activities.

TeMix Inc.

TeMix Inc. is a leading provider of transactive systems and services to the power and energy industry. The TeMix Platform™ can host the full scope of transactive services—from generator to transmission, to distribution, to consumers, and the devices on the Internet of Things. TeMix has played an active role in the development of transactive energy protocols and standards.

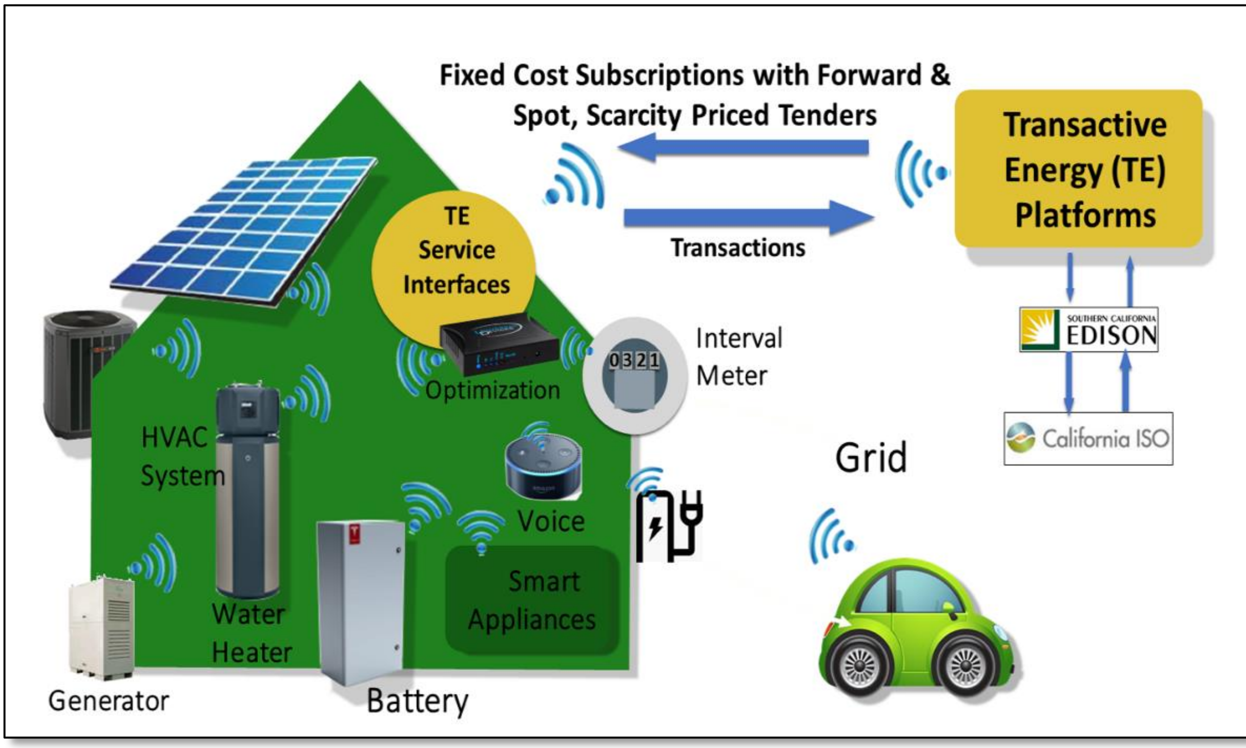
TeMix is technically a subcontractor to Universal Devices for this grant but is a full partner with the company for this RATES project. TeMix oversaw and developed transactive energy platforms, interfaces, tariffs, and device agents used in this project.

RATES High-Level Overview

This section provides a high-level overview of the RATES development and pilot. RATES focuses on serving retail facilities with one or more energy use, generation, and storage devices, as illustrated in Figure 1. These facilities can be of any type, including residential, commercial, industrial, agricultural, electric vehicle charging stations, and standalone generation and storage, although the primary focus of this project is residential.

RATES uses a simple, innovative retail rate plan (tariff), designed with support from SCE and CPUC. The tariff offers electric customers "subscriptions" for fixed hourly kW of electricity shaped to their historical usage at a fixed monthly cost. The monthly cost is based on their current tariff. If the customer uses more or less kW in an hour than subscribed, RATES automatically sells back kW or buys more kW at real-time tendered prices that vary with supply, demand, and other grid conditions. This tariff is called a subscription transactive tariff, designed for low-cost automation and billing.

Figure 1: RATES High-Level Overview



Source: TeMix Inc.

Customers do not need to see or understand, unless they are curious, the technical details of RATES because the customer interface is very simple. Ultimately, customers who install home automation for convenience, entertainment, and security will gain savings and help California achieve its clean energy goals by switching from their current tariff to a new tariff and then, with their permission, some of their devices will change when they operate to use more low-price electricity from abundant renewables generation (such as solar) and less from high-price, high-carbon generation. Customers will still have as much comfort and convenience from using electricity devices as they desire, while saving money on their bills.

This section provides further high-level explanations of RATES. Please see the appendices for more technical details on RATES.

Each customer, as shown in Figure 1, receives transactive buy and sell tenders (offers) from SCE through a transactive energy platform. SCE publishes the tenders according to a schedule determined in part by the publication schedule of wholesale prices by the California ISO. SCE sends hourly tenders to the customer for about the next 24 hours, and they are updated hourly. SCE also sends four 15-minute tenders just before each hour. Finally, a five-minute tender is sent just before each five-minute interval.

As will be described shortly, optimization agents help the customer decide how much of each buy or sell tenders to accept as transactions. As illustrated in Figure 1, transactions are sent back from the customer transactive energy service interface to the TeMix Platform, recorded in ledgers, and then passed to SCE. The transactions specify the price and quantity, and the TeMix Platform performs the calculations to determine the total energy schedules with the California ISO and the financial payments (bills) between customers and SCE.

The net purchases from transactions from all participating customers is totaled for a set of future intervals. The net purchases of the nonparticipants in RATES is forecasted using historical load data and weather forecasts. The net purchases for all customers from SCE is the sum of the participating and nonparticipating load.

A "market maker" algorithm issues new tenders at prices that may vary depending on the net purchases. These tender prices are from transactive pricing formulas that reflect overall supply, demand, and load placed on distribution circuits and wholesale generation.

The almost continuous creation of new tenders and the total customer buy, sell, and net purchase responses will lead to an efficient supply and demand balancing in the retail and wholesale markets.

The tenders are received by the transactive energy service interface and optimization agents for individual devices, as illustrated in Figure 1. Voice assistants can be used by customers to set their preferences.

The Universal Devices ISY (the black box illustrated in Figure 1) serves as the communication and device control system for the facility's devices. The ISY communicates with optimization agents for each controllable device that was developed by TeMix. The optimization agents' goal is to save money for the customer by shifting and shaping each device's electricity use and production while still meeting the customer's requirements. The optimization agents determine the response of devices to the forward (future) tender prices, weather forecasts, and customer preferences. Participation in RATES is much easier when agents hide the complexity of RATES from the customer.

Based on the optimization results, the agents automatically accept portions of the tenders and create forward transactions for electricity in hourly, 15-minute, and five-minute intervals with the tendering parties. These forward transactions may execute seconds, minutes, or hours ahead of the start of each delivery interval. Additionally, balancing transactions based on the difference between the net position from all forward transactions and the meter reading for each metered interval execute automatically after each interval ends.

The following sections further explain how RATES works.

RATES Architecture and Interfaces

There are two ways to view the RATES architecture and its interfaces:

- Flow of tenders and transactions among the major parties, as shown in Figure 2.
- Data communication among the computer servers and devices, as shown in Figure 3.

Rates Informational Architecture

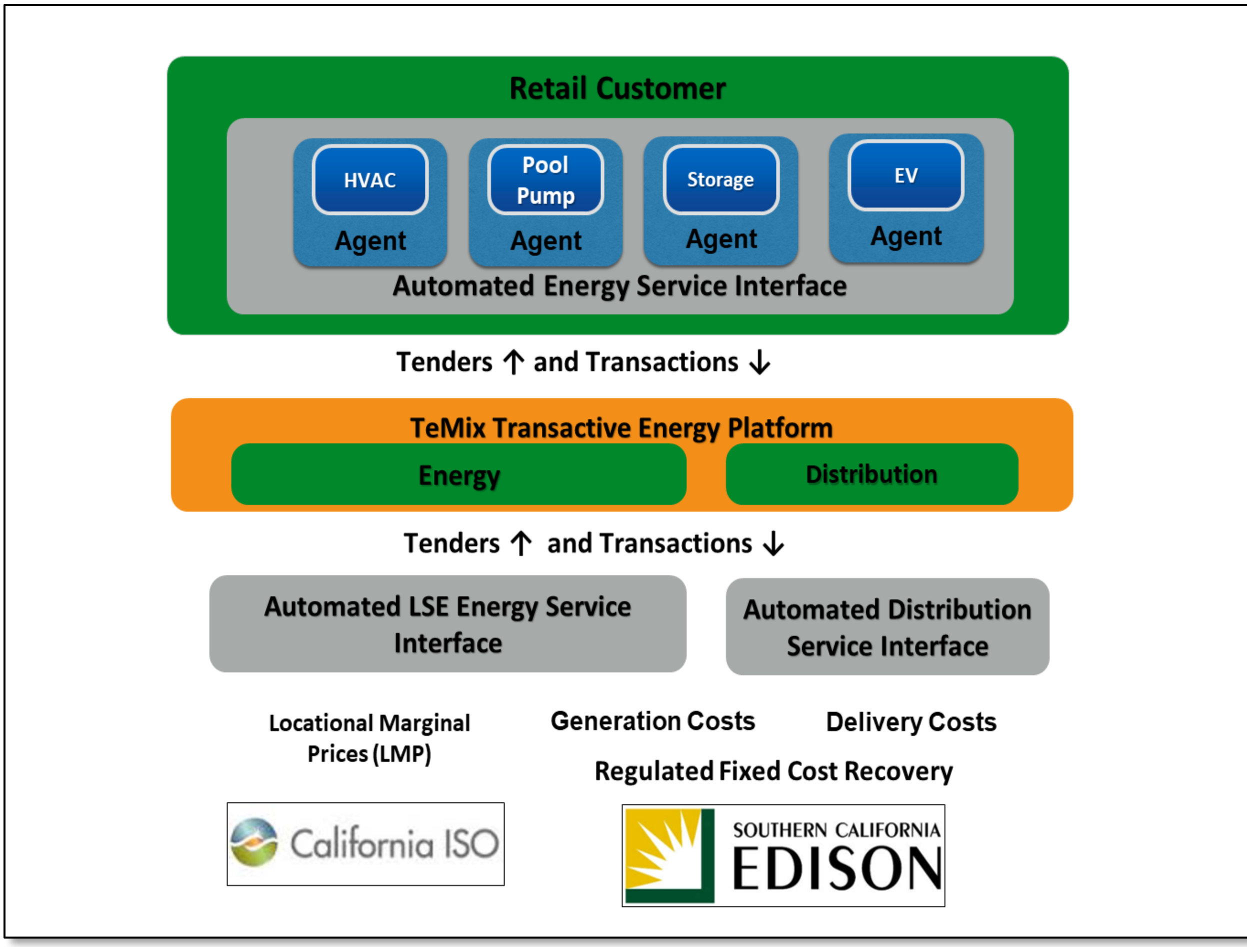
At the center of Figure 2 are the transactive energy platforms based on the TeMix Platform. Currently, RATES uses a single TeMix Platform, but multiple, decentralized platforms can be used to scale to extremely large numbers of parties and transactions.

At the bottom of Figure 2, the platform receives tenders for energy from a LSE at wholesale substations. The LSE uses an automated LSE service interface (ALSI) to create the tenders.

The platform also receives tenders from the distribution operator for the transport of energy from the substations to the customer facilities. The distribution operator uses an automated distribution service interface (ADSI) to create the tenders.

For this project, SCE is the load-serving entity and distribution operator. SCE also interfaces to the California ISO.

Figure 2: Informational Architecture of Interactions Among Parties



Source: TeMix Inc.

In addition to supporting communication of tenders and transactions among the parties, a primary function of the TeMix transactive energy platform is to host ledgers of accepted transactions among parties. Multiple ledgers can be used within each of the multiple decentralized platforms. Commercial cloud-based database systems are used to host the ledgers, allowing for a wide range of secure database technologies.

System loads and costs are used as inputs to the subscription transactive tariff for the load-serving entity and distribution operator. The calculation of the dynamic tariff prices includes the California ISO locational wholesale marginal spot prices. The tariff also includes long-term subscriptions for energy and transport that the project team later describes.

At the top of Figure 2 are the retail customer facilities from the transactive energy service interfaces mentioned earlier, the energy management system, devices, and the facility meter.

Secondary transactive energy service interfaces provide cloud-based device operators the option to manage their device operations in response to tenders.

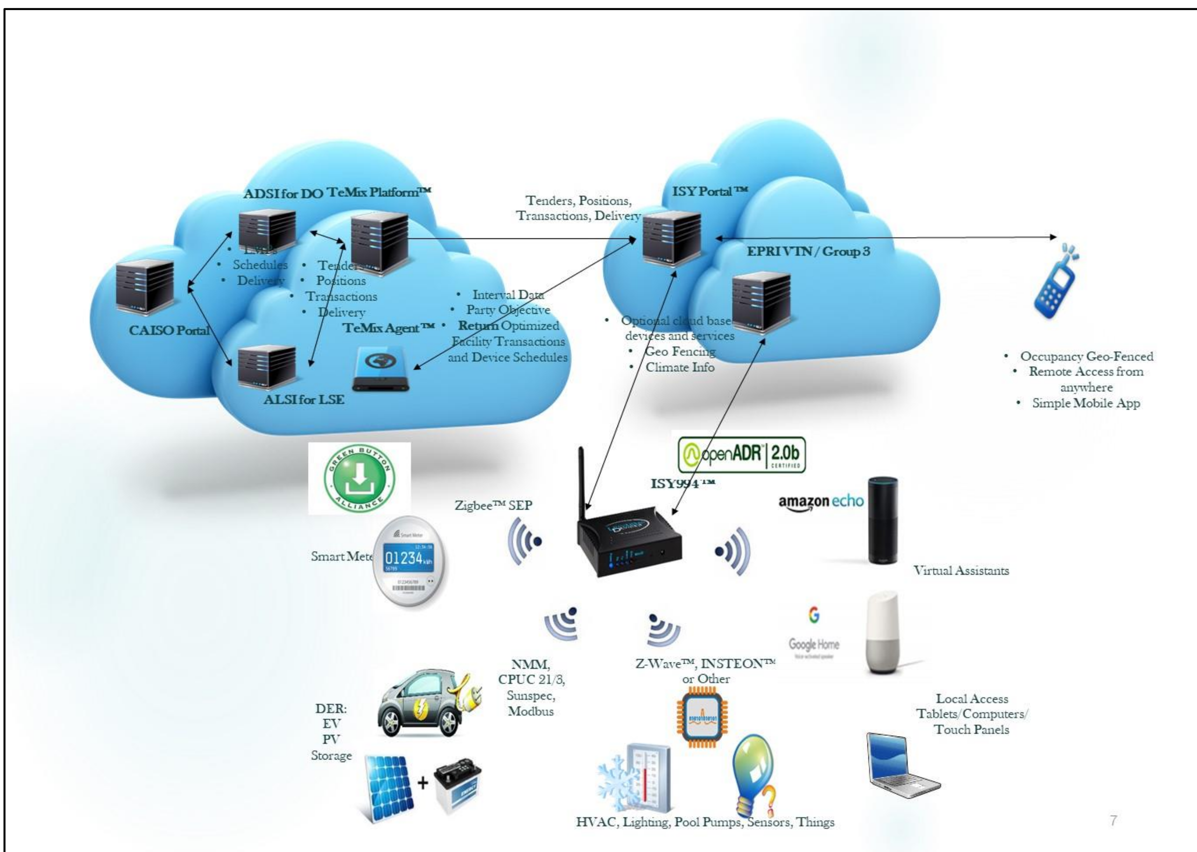
The TeMix Platform and the associated tenders, transactions, and positions use structures designed for high volume and simplicity. A 2011 Grid-Interop Paper defines the structures (Cazalet, Automated Transactive Energy (TeMix), 2011). Among the key structural elements are:

- All intervals are nested and compatible with intervals in the wholesale market. For example, three 5-minute intervals are within each of four 15-minute intervals that are within each hour interval of a day. Day intervals are nested within month intervals, and month intervals are within year intervals.
- Energy is measured as the kWh average over an interval. The kWh for each interval is the kW for the interval times the duration in hours of each interval.
- The position in any interval is the sum of all transaction kW for the interval, taking account of the sign (buy/sell) of each transaction. The position in each interval includes the positions in all longer intervals that include the intervals, plus the average positions in all subintervals.

RATES Technical Architecture

Figure 3 shows a different view of the RATES shown in Figure 2.

Figure 3: Technical Architecture of RATES Interactions



Source: Universal Devices

At the top left of Figure 3 are the cloud-based, TeMix-related systems currently hosted on Microsoft's Azure cloud. Also shown is the Green Button interface to the SCE smart meter data. At the top right are the cloud-based Universal Devices–related systems that interface directly with the ISY in the facility, with the TeMix Agent and the Energy Expert voice virtual assistants based on Amazon Alexa and Google Home. The ISY in the facility has two-way wireless communication with the SCE meter and devices enabled for communication and control. The voice devices interface with the ISY Portal through the Amazon and Google clouds. The ISY in the facility communicates with the ISY Portal™ in the Amazon cloud that communicates with the TeMix Platform and the TeMix Agent.

California ISO, Distribution Operator, and Load-Serving Entity Service Interfaces

The California ISO hosts a portal with an application programming interface (API) that posts hourly, 15-minute, and 5-minute locational marginal prices (LMPs) at transmission-level substations on their transmission grid at regular intervals. There are two TeMix service interfaces, ALSI and ADSI, to the California ISO portal. This pilot used the SCE's Moorpark Transmission Substation LMPs provided by the API, but multiple other transmission substations to the California ISO could be used.

As described earlier, the ADSI and ALSI are automated "market makers" acting on behalf of SCE as a distribution operator and load-serving entity. In the case of a CCA, it would be the load-serving entity, while SCE would be the distribution operator. If the California ISO were willing, it could be the "market maker" for wholesale tenders at the wholesale retail interface. However, until then, the load-serving entity in its role as a scheduling coordinator in the California ISO market can be the market maker for retail tenders that include tenders based on forecasted and actual wholesale LMPs.

The ALSI creates the energy tenders to customers based on the associated California ISO LMP and tariff pricing calculations that the project team shortly explains. The tender prices recover more of the generation fixed costs with higher prices when the generation system is more heavily loaded. These energy tenders are for delivery of energy at the wholesale substation.

Similarly, the ADSI creates the transport tenders to customers that recover (1) more of the fixed costs of distribution circuits from the substation to the customer facility when the circuit is more heavily loaded in either direction and (2) the cost of the resistance energy losses based on the current LMP that increase with the flow on the distribution circuit. The California ISO LMP is necessary to calculate the cost of the resistance energy losses.

The tenders to customer facilities bundle the energy and transport tenders, adding the price of transport to the price of energy. Each tender is to a specific customer with a limited quantity to the customer and a transport price that could depend on locations along the circuit.

Tenders are published frequently, so the limits on tender size should not be a problem for customers and can be adjusted by the ADSI and ALSI as required. The limits support price discovery, grid stability, fairness, and avoidance of manipulation.

Subscription Transactive Tariff

RATES employs a CPUC-approved, experimental retail tariff. For SCE customers, the retail tariff is designed to recover the investment and operating costs of the SCE load-serving entity and the SCE distribution operator.

The RATES tariff is a subscription transactive tariff, which is simpler and less risky for customers than a conventional flat or time-of-use tariff with increasing block rates, fixed or minimum monthly charges, seasonal and locational estimated baselines, demand charges, and DR programs.

The subscription transactive tariff combines (1) simple energy buy and sell tenders (offers) from the load-serving entity sent via the internet to customers and their devices and (2) a subscription for a customer-determined quantity (kW) of energy in each hour of the year at a predetermined cost for each month.

The SCE load-serving entity tariff bundles the SCE distribution operator tariff for delivery to the customer. In the case of a community choice aggregator served by the SCE distribution operator, the CCA load-serving entity tariff bundles the SCE distribution operator tariff. In other words, the customer only deals with the SCE load-serving entity or the CCA, and not the SCE distribution operator.

RATES can use different variations of the subscription transactive tariff. The tariff tested in this pilot is a "proof-of-concept" that tests the feasibility of the complete subscription transactive tariff concept, but it leaves many flexible specifics for further policy analysis, compromise, and regulatory oversight. Having demonstrated the mechanics of a subscription transactive tariff helps later efforts to refine the tariff and its inputs.

Fixed Cost Recovery for the Subscription Transactive Tariff

Two categories of "fixed costs" are recovered by the subscription transactive tariff.

- Billing, metering, access, and public purpose costs (including capacity costs), are typically recovered in the monthly subscription cost in addition to the costs of the subscribed kW quantity in each hour of the month.
- Long-run marginal capacity costs are recovered in the tender prices using scarcity pricing, as described in the next section.

To illustrate, even if a customer's subscription is for zero kW in each hour of a month, the fixed costs for billing, metering, access, and public purpose costs will be recovered in the subscription cost.

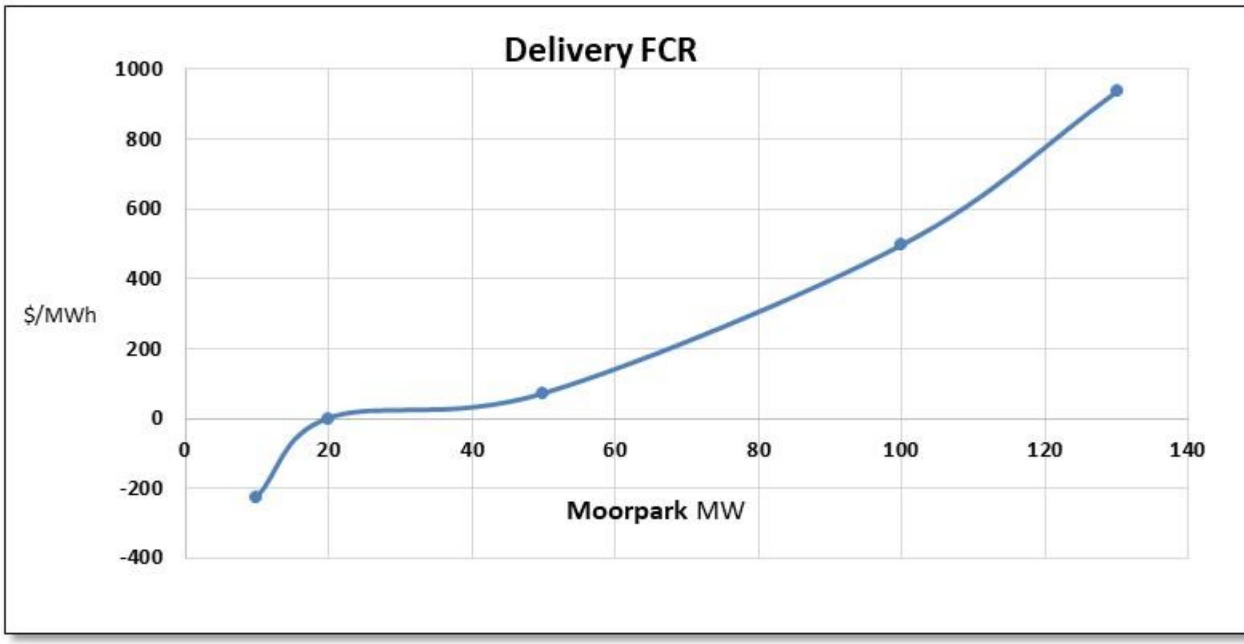
Scarcity Pricing for the Transactive Tenders

RATES uses granular scarcity pricing to develop the tender prices for the SCE distribution operator and load-serving entity. The concept is simple: recover more of SCE's fixed costs (long-run marginal capacity costs) at higher prices in intervals when the use of generation and distribution is high and less at lower prices when usage is low. The intervals can be for an hour, 15-minutes, or 5-minutes' duration.

The appeal of scarcity pricing is that there is no requirement to specify artificial capacity products that are impossible to define in markets with highly variable renewable supply and price responsive end use. The granular (interval-specific and location-specific) scarcity prices pay for the necessary capacity.

With scarcity pricing, the price of a service is its variable $/Megawatt-hour(MWh) cost plus a $/MWh fixed cost recovery factor for each hour, which when multiplied by the MWh of the service provided in each hour of a year recovers the ($/MW-year) fixed cost of the service. Each fixed cost recovery is determined by a curve that is adjusted to recover the annual fixed cost associated with each of the fixed cost categories. The fixed cost recovery curve for delivery costs from the SCE Moorpark substation is a function of the total load at the Moorpark substation in Figure 4. For this circuit, negative prices at low load on the circuit support load increases above minimum safe levels.

Figure 4: SCE Moorpark Fixed Cost Recovery for RATES Pilot

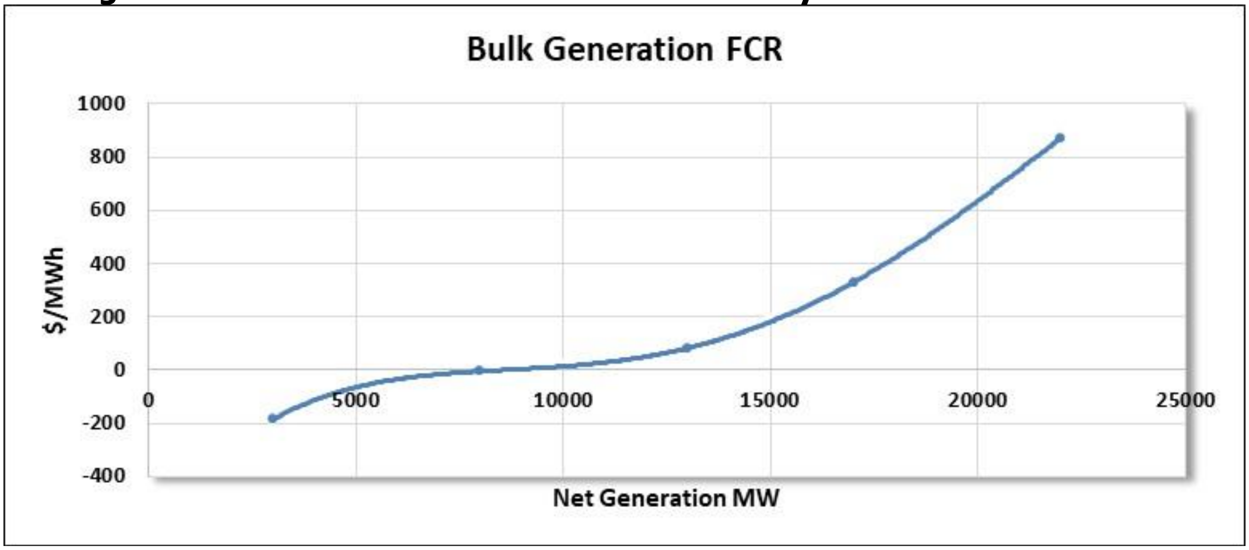


Source: TeMix Inc.

The RATES energy price is the California ISO locational marginal price plus two fixed cost components for generation capacity. The fixed cost for energy generation is allocated among supply and ramping. The allocation, based on SCE policy, is 60 percent of the annual generation fixed cost for bulk generation supply and 40 percent for three-hour ramps. The three-hour ramp for an hour is the current net load for the SCE load-serving entity for the hour less the net load three hours earlier.

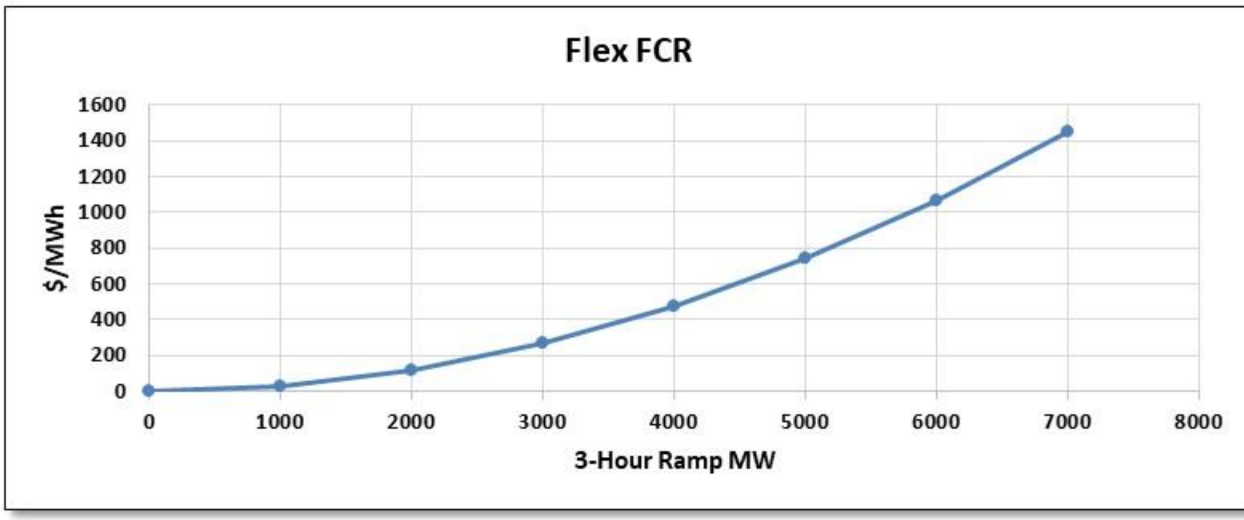
The fixed cost recovery curve for bulk generation is shown in Figure 5, and the fixed cost recovery curve for three-hour ramping is shown in Figure 6. The price for bulk generation goes negative below a stability limit specified by SCE.

Figure 5: Bulk Generation Fixed Cost Recovery Factor for RATES Pilot



Source: TeMix Inc.

Figure 6: Three-Hour Ramp Fixed Cost Recovery Factor for RATES Pilot



Source: TeMix Inc.

As described in APPENDIX H:
Subscription Transactive Tariff Tender Price Calibration, the hourly scarcity pricing curves are scaled up or down until the revenue from each component curve (price × MW × 1 hour) for all 8,760 hours of the year equals the annual cost of service for the component.

In this pilot, only 2015 data were available early in the project. The calibration of the scarcity curves was therefore carried out for 2015 as a test year.

The bundled tender price is the LMP plus base generation plus flex generation plus delivery prices. If the customer uses more than the subscription kW in any interval, the customer buys the additional kW at the bundled price. If the customer uses less, the customer sells the extra kW at the bundled price.

Subscription Development

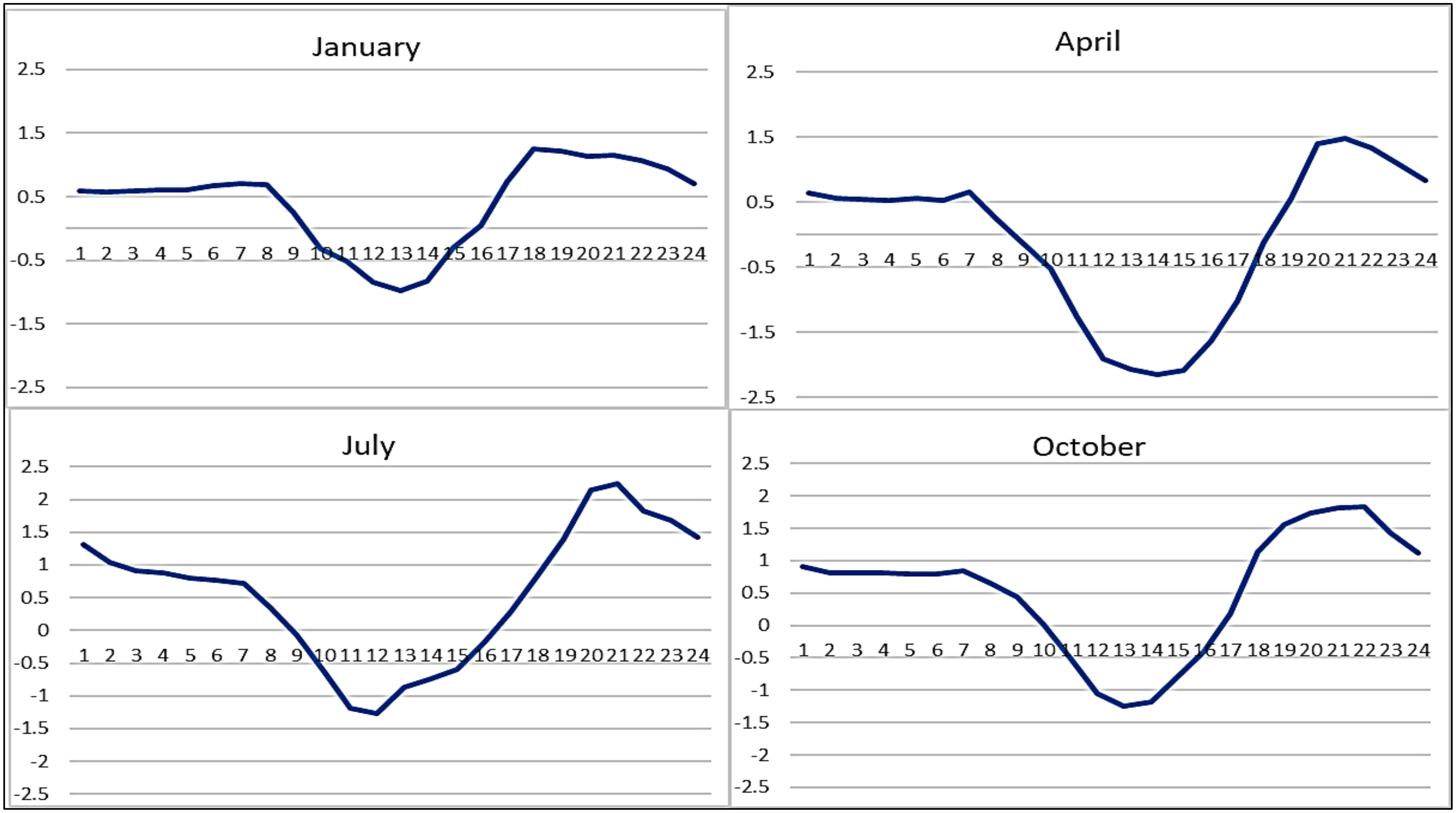
The subscriptions for each RATES customer are developed from historical meter data automatically downloaded from the SCE Green Button meter data system.

This historical meter data is processed into average hourly quantities for each weekday and weekend for each month of the year. Figure 7 shows subscription quantities for weekdays of selected months for a RATES participant with a solar system. Figure 8 shows a non-solar customer's subscriptions for selected weekday months.

This approach to the development of subscriptions enables the creation of subscriptions that involve no customer billing changes and load-serving entity and distribution operator revenue changes if the customer uses about the same hourly kW of electricity.

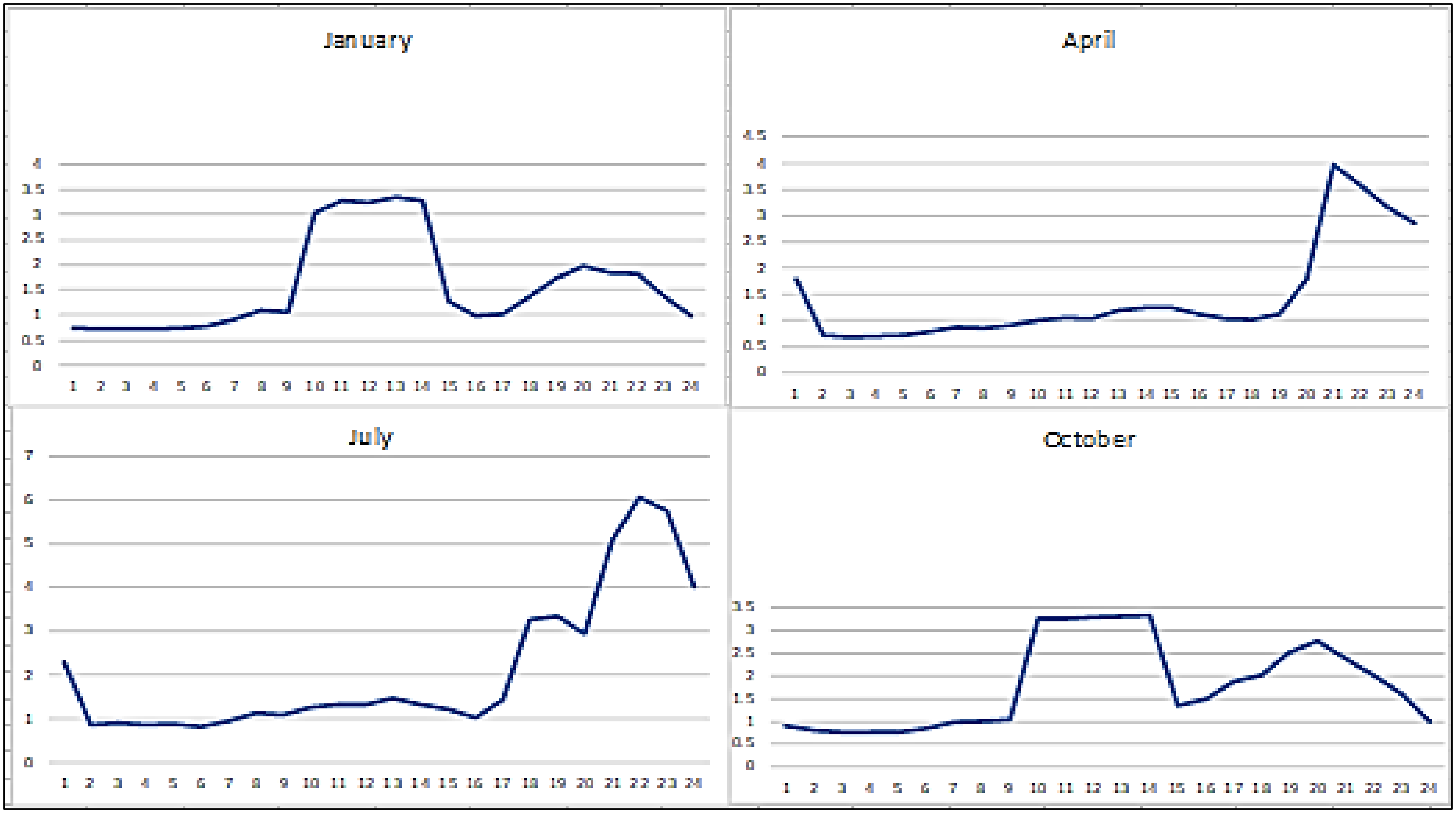
A more advanced RATES systems application would have the SCE "market maker" provide tenders to allow customers to increase or decrease their subscribed quantities well ahead of the day-ahead transactions (for example, monthly) to modify the subscribed quantities. Customers may want to modify their subscriptions because they may have purchased a solar system, electric vehicle, heat pump, storage, or some other devices. Changes in subscription could require changes in monthly payments. A decreased monthly payment might support a new device such as a battery or an electric heat pump for HVAC.

Figure 7: RATES Solar Participant's Weekday Subscription, Hourly kW by Month



Source: TeMix Inc

Figure 8: RATES Non-Solar Participant's Weekday Subscription, Hourly kW by Month



Source: TeMix Inc.

The customer's current tariff rate plan determines the monthly payments for a subscription. The monthly payment retains any benefit to the customer from residential solar net metering. For the duration of the subscription, the net-metered solar customer is not disadvantaged by a transition to the subscription transactive tariff. It also means that if the customer installs battery storage, the customer will get the full benefit of charging when the hourly or five-minute tender prices are low and discharging when the hourly or five-minute tender prices are high. This, of course, is exactly what is required to support increased solar and storage.

The subscription transactive tariff by design should not create substantial structural winners and losers because the subscription costs and quantities reflect the customers' historical usage patterns and their current tariff.

Transitioning to the subscription transactive tariff should not require a massive new rate-making process. The pilot subscription tariff used the customer's existing tariff and usage patterns to set the subscription quantities and monthly subscription costs. The dynamic pricing formulas are simple and calibrated to recover only approved revenue requirements under existing tariffs.

The subscription transactive tariff can be opt-in for existing customers. Ideally, customers installing solar, storage, EV chargers, electric water heaters, variable speed pool pumps, and HVAC heat pumps eventually should be required to agree to the subscription transactive tariff.

The subscription transactive tariff used in this pilot does not eliminate bill variability due to factors such as weather; however, to mitigate bill variability, customers that allow an HVAC agent to manage their thermostat during hot weather will have the opportunity for substantial savings by precooling and accepting a lower comfort level when prices are extremely high.

Customers could be offered subscriptions indexed to temperature, so in extreme weather situations, the tender prices would be higher or lower. This would reduce customer bill volatility without affecting the effectiveness of the dynamic tender prices.

Another alternative is to have a set of standard subscriptions with different hourly shapes within the month. Customers might be assigned to the subscription shape that fits their typical use, or they might be given the opportunity to select a subscription shape. Standard subscription shapes might reduce the expense of developing subscriptions.

RATES Experimental Tariff Billing

Appendix J contains the advice letter submitted by SCE to the CPUC for the transactive tariff for this project. An advice letter is a standard way to inform the CPUC of actions that staff may approve. Additionally, the RATES team met with SCE and CPUC staff and held several calls to support SCE's development of the advice letter.

The advice letter specifies two bills:

- SCE monthly bill: the customer bill using the customer's current tiered or time-of-use tariff.
- RATES monthly bill: the customer bill using the customer's RATES subscription transactive tariff.

The metered kWh during each five-minute interval of the month applies to both bills.

Participants pay their SCE monthly bill and also get a RATES monthly bill. The participants receive a rebate for the cumulative monthly bill savings for the RATES bills over the SCE bills.

Energy Expert

Energy Expert is the two-way voice interface to RATES. It was specifically designed to make it easier for the participants to interact with RATES, as well as providing the team with additional metrics for customer engagement. Energy Expert uses the Amazon Alexa system, but it can use other voice response systems such as Google Home. Appendix E documents the Energy Expert voice commands and responses.

For a manually controlled device such as a washer or dryer, the customer can ask Energy Expert: "When is a good time to run my dryer?" The response would be something like "The best time is now, and it will cost 16 cents, but if you wait until 6 pm, it will cost 2 dollars and 34 cents."

The prices used to estimate these costs are from the tenders from the TeMix Platform.

For automated devices such as heating, ventilation, and cooling (HVAC), battery storage, and pool pumps, Energy Expert allows the customer to communicate settings through the ISY Portal to the TeMix Agent. The agent schedules the operation of each device and provides the device schedules to the ISY Portal/ISY to automate the operation of devices.

For example, in the case of the air conditioner, the customer can say

- Set my AC preferred temperature to 72 degrees (Fahrenheit), or
- Set my AC comfort level to medium.

Based on these two inputs and the tender prices for the next several hours, the TeMix Agent creates a thermostat setpoint schedule depending on the current price and the forward prices. The setpoint schedule is then sent to the ISY/ISY Portal and, in turn, to the thermostat. For example, in cooling mode, the agent may lower the setpoint by precooling before higher forward prices occur. Precooling at lower prices can save money for the customer, and the comfort level set by the customer determines how much the actual facility temperature differs from the customer's preferred temperature.

As illustrated above, the RATES system does *not* require the customer to understand how many kWh to buy or sell and at what price. Electricity usage is normally conveyed to the customer by RATES in dollars, and not kWh, which many customers do not find helpful.

ISY and ISY Portal Energy Management System

The ISY is an autonomous and low-cost energy management hardware and software system that supports two-way communications with devices and things, including the smart meter. The ISY uses a cloud-hosted platform, the ISY Portal, to facilitate cloud-centric communications and services. The ISY Portal interfaces with the TeMix Platform and TeMix Agent, Amazon Alexa, Google Home, Nest, and Ecobee thermostats, SolarEdge inverters, and many others.

A RATES client was developed as a plugin to the ISY Portal such that the main features would remain intact for existing customers while isolating the extension of those features to RATES customers. For the sake of simplicity, the combined system is referred to as the ISY Portal.

To make sure strict cybersecurity standards are adhered to, for each participant the ISY Portal uses a unique OpenADR certificate with an associated fingerprint. A secure linkage and authentication process was developed to link an ISY Portal account to a TeMix account that uses digital certificate fingerprints for authentication. No other entity can participate in RATES without having digital certificate security for the channel end-to-end.

When the ISY Portal receives a set of tenders from the TeMix Platform for a customer facility, the TeMix Agent optimizes the scheduling of managed device operations. The ISY Portal also manages customer interactions with Alexa through Energy Expert. These include customer preferences, queries, and smart home commands.

A novel feature of ISY Portal automatically calculates energy usage of devices by (1) going into fast polling mode and thus reading the facility meter every two seconds (instead of every 20 to 30 seconds) and (2) automatically turning the device on/off a few times till such time that a relatively accurate pattern of energy usage is determined. This improves the accuracy of device usage estimates.

Delivery records are also created on the TeMix Platform based on meter reads by the ISY Portal or using Green Button meter data from the same SCE meter.

TeMix Agent

The TeMix Agent hosts software agents for each type of device that can be managed automatically or with customer choices. With the permission of the customer, the following device classes are managed automatically:

- HVAC—heating, ventilating, and cooling
- Pool pump
- Battery storage
- Electric vehicle charging

No electric water heaters were available in this project, but a prototype electric water heater agent was developed.

Other devices such as electric dryers, clothes washers, and dishwashers can be scheduled by the customer based on their cost of operation at forward/future tender prices over the next day.

The agents for the HVAC, pool pump, and battery storage are described below. The detailed inputs, outputs, constraints, objective functions and mathematical programming algorithms for each agent type are further described in APPENDIX G:
TeMix Agent.

HVAC Agent

The heating and cooling agent for a facility determines the temperature setpoints for the thermostat. The agent attempts to save money for the customer, given their preferred interior temperature, comfort versus savings level, and exterior temperature forecasts from a weather service. The agent estimates the kW in each hour, 15-minute, or 5-minute interval required by the temperature setpoints sent to the thermostat via the ISY.

The ISY Portal accurately estimates the actual kW used by an HVAC in each five-minute interval, even though there is no actual electric meter on the HVAC system.

The agent has access to the history of interior and exterior temperatures. Given this history, the agent estimates by machine learning two parameters:

- Flow parameter—the contribution to interior temperature change per hour from internal heat sources such as people and electrical devices.
- Flux parameter—the contribution to interior temperature change per hour from the difference between the exterior temperature and the interior temperature.

Since the pilot focuses on electricity, the agent does not manage gas heating. Natural gas tenders and transactions and gas heating management can be done by RATES if so configured. The agent does manage heating and cooling with an electric heat pump.

Machine learning estimates two additional parameters regarding the thermodynamics of the building and the HVAC system.

- Cooling effectiveness parameter—the change in interior temperature per kWh of cool mode operation.
- Heating effectiveness parameter—the change in interior temperature per kWh of heat mode operation.

Together these four parameters allow the agent to model the change in interior temperature from hour to hour as a function of the exterior temperatures and the kW of electric energy for cooling or heating in each hour.

The management (optimization) of the thermostat for the next hour looks forward over a 10- to 24-hour horizon depending on how many buy and sell tenders are available to the facility. The optimization objective is to maximize the net benefit to the customer of the HVAC operation.

The net benefit has two components: cost and benefit. The cost in each interval is simply the kW used in each hour times the tender price times the duration of the interval in hours. The benefit in each hour depends on the difference between the customer's preferred interior temperature and the actual interior temperature. The highest benefit is when the temperature difference is zero. The benefit decreases with a larger absolute difference from the preferred temperature.

The customer is able to set the HVAC mode (heat, cool, auto, and off), the preferred heating and cooling temperatures, and a preferred savings versus comfort level using the Energy Expert voice system.

An optimization problem is formulated to maximize the objective function subject to constraints. The constraints are the maximum kW input to the HVAC and the equations that determine the change in the facility interior temperature as a function of the exterior temperature, flow, flux and heat, and cooling effectiveness. The thermostats typically only provide a setpoint resolution of one degree Fahrenheit, so integer constraints are necessary.

Actual operation of the HVAC agent is shown in the project results in Chapter 3.

Pool Pump Agent

The pool pump agent is configured by the customer using the Energy Expert voice interface.

In this pilot, the pool pump is either on or off in each hour, as there were no variable speed pumps.

The customer specifies the number of hours per day of pumping and the maximum number of starts per day. The customer can set a blackout period when the pump will not be allowed to run.

The agent minimizes the cost of operation based on the current hourly tender prices for each day, subject to the total hours of pumping requested, the blackout hours and the maximum number of starts.

The planned operation before the midnight start of the day is based on currently available forward tenders. As these tenders expire and new tenders are received, the agent may change the schedule for the rest of the day; sell back what was previously purchased for a given hour and buy in a different hour if the changes will benefit the customer.

Typically, the customer will set and forget the automated pump operation, perhaps adjusting the pump operation required in hours per day, seasonally. At any time, the customer can ask Energy Expert how much has been spent on pool pump operation in the previous hour, day, or 30 days, for example.

Typically, with the RATES experimental tariff, the pump runs midday, consuming more midday solar energy.

If the pump is variable speed, then the agent can change its operation to respond to five-minute price spikes or drops.

If the pool pump controller is a third-party cloud-based system, then the third-party vendor can be authorized to receive buy and sell tenders from RATES and schedule the operation of the pool pump to save the customer money. Until RATES is in commercial operation with a fully deployed transactive tariff, vendors may not be interested in making the necessary software changes.

Battery Storage Agent

The battery storage agent maximizes the discharge revenues less the charge costs over the remaining hours of each day, starting at midnight and subject to certain constraints identified below.

Each battery has a kWh energy storage capacity, but typically the customer will specify a minimum and maximum state-of-charge (SoC) percentage. Each battery has a round-trip efficiency that is discovered by machine learning in actual operation.

Each battery also has a maximum kW discharge and charge rate.

The net revenue includes wholesale, distribution (from reversing flow), and ramping revenues. Because of the scarcity pricing formula, capital and operating costs savings are included in the prices and daily net revenues.

The actual dispatch of a battery is shown in Chapter 3.

Electric Vehicle Agent

The EV agent minimizes the charge costs from the current SoC percentage to that requested by the owner by a given time.

Importantly, the agent avoids charging when the cost to the grid is high and benefits the customer by charging when the cost to the grid is low.

If the EV, when connected to the charger, encounters very low or negative tender prices, it will automatically charge to a higher SoC than the one set by the customer.

The charging algorithm also learns how much battery discharge occurs in support of the vehicle's system in standby mode. For a Tesla Model S, this is about 3 kWh per day, and the charging algorithm often can replace this energy at very low or negative tender prices, saving the customer much money. Replacing this standby energy loss when there are millions of EVs on the California grid can save much money and consume otherwise wasted solar energy.

Facility Transactions

Each managed device agent determines the optimized kW for each managed device. The other non-managed kW amount is forecasted using machine learning based on the difference between the kW five-minute facility SCE meter readings and the total kW of all managed devices, and is associated with a virtual residual device.

The total facility kW planned for each future interval is the sum of all managed device kW plus the residual device kW. If a device is supplying kW, the kW will be negative.

The net position kW in each interval is requested from the TeMix Platform. If the total facility kW is greater than the net position kW for an interval, then a transaction is executed against the sell tender by SCE for the interval; if the total facility kW is less than the net position kW for an interval, then the transaction is executed against the buy tender by SCE for the interval.

SCE Smart Meter Interface

For the sake of accuracy, smart meters are polled every 20–30 seconds. Using the area under the curve representing the five-minute interval of 20–30 second readings, the ISY Portal determines the average net kW used over the interval. The ISY Portal then sends the meter reading to the TeMix Platform, which enters the reading into the delivery records for the facility meter. These direct five-minute readings help coordinate with the California ISO, which operates on the same five-minute intervals.

Green Button Meter Data Interface

SCE collects 15-minute meter readings and other meter data over its private communications network. SCE then validates these meter readings and makes any necessary changes for missing reads or other errors.

Each registered RATES customer must register with the SCE Green Button system to have its meter data automatically downloaded to the TeMix Platform using Green Button protocols supported by SCE.

If the average of the five-minute kW readings from the ISY Portal is different from the 15-minute kW readings, then the TeMix Platform will adjust the 5-minute readings to be consistent with the 15-minute readings from the Green Button system.

If a five-minute meter reading is not available from the ISY, then the TeMix Platform develops a virtual (estimated) five-minute meter reading based on other five-minute readings and the 15-minute readings.

The SCE Green Button system sends the preliminary Green Button 15-minute data to the TeMix Platform a few days after each day. It sends the final Green Button 15-minute meter data once per month. In both cases, the meter data are processed automatically upon receipt.

Ex-Post Balancing Transactions

Ex-post transactions are created when the ISY Portal receives the five-minute meter reading directly from the SCE meter and the ex-post five-minute buy and sell balancing tenders from the ALSI. The ISY Portal accepts a buy or sell tender to create a transaction for the difference between the five-minute meter reading and the actual net usage less previous net purchases and sales, including the subscribed quantities.

If the ISY Portal is unable to complete this ex-post transaction or there is a change in the meter readings based on the Green Button meter data, then the ALSI will create any necessary ex-post transactions.

If a direct meter reading by the ISY energy management system is not enabled because of communication issues, then the ALSI can carry out the ex-post balancing transaction and settlement calculation when the preliminary Green Button readings are available within about two days.

For implementing a simplified version of RATES, appropriate to some low-use customers, it can be operated for those customers without an automated energy management system interfacing to the meter and the devices using the ALSI ex-post transaction process. This option was outside the scope of this pilot, but the ALSI is prepared to support such an option.

Additional Interfaces, Geofencing, and Remote Access

The ISY Portal supports remote access and geofencing capabilities. Remote access enables customers to control/monitor all their devices/settings remotely using any browser, including mobile. This does not require any modification to a router (such as port forwarding) and network gear.

Geofencing is accomplished by defining an area around the house. This is done via mobile application and requires active customer participation and input but, due to the complexity involved, initially these were created by the installation technician. The idea is that when the mobile device is within the fence, ISY Portal will set occupancy to true and otherwise to false. This enables the TeMix agent to use occupancy information as another parameter for optimization.

Since geofencing requires the app to run in the background on participants' mobile devices, some participants used it, but most participants disabled it because they didn't know what it was. To mitigate this issue, the team provided an additional simple occupancy dialog using the Alexa Energy Expert skill. Now, participants can say "I'm leaving" or "I'm home."

RATES Pilot

Pilot Participant Selection

After multiple meetings to analyze the geographical requirements for the pilot SCE, TeMix and the Universal Devices teams identified the SCE distribution circuits and communities connected to SCE's Moorpark substation as the focus for this project. The communities in this area are said to have a strong interest in clean energy and energy management, including customers with solar and electric vehicles.

An additional factor in the circuit selection was based on SCE anonymous customer meter data, which was analyzed by the TeMix team. The sample data SCE provided includes anonymous customer three-year load data for solar and non-solar customers. SCE also provided sample circuit data that enabled the team to test alternative ways to create energy and distribution subscriptions for the volunteer customers and simulate the effect on their bills.

To reach potential participants within the selected circuit, Universal Devices reached out to the local state senators, Senator Fran Pavley, and Senator Henry Stern and his office. Senator Stern's staff provided continuous support in identifying ways to recruit potential participants by reaching each mayor within the cities identified as part of the Moorpark substation circuit. A representative from Universal Devices was encouraged to attend city council meetings and offer local communities the opportunity to become participants in this study.

Each participant was given verbal and written explanations detailing what they will receive by participating in this pilot and what will be required of them. The written documentation is included in APPENDIX A:
RATES Stakeholder and Pilot Participant Report.

To comply with the Information Practices Act, as codified in California Civil Code, section 1798, pilot participants were required to complete either a Customer Information Standardized Request (CISR) form or written consent that allowed the pilot team to have access to their current and historical electric usage data. The information provided by the pilot participants was maintained securely and was not distributed to anyone who is not directly involved in this grant. Only Universal Devices and TeMix team members who have been approved as part of the grant's working team have access to pilot participants' personally identifiable information.

Regular Installation

The complete list of hardware that was available to pilot participants is listed in APPENDIX A: RATES Stakeholder and Pilot Participant Report. It included a home automation Z-Wave enabled hub, a communicating Z-Wave thermostat by RCS, a Z-Wave pool pump sensor, and an Amazon Alexa Dot.

The pilot's installer visited each pilot location at least once. He delivered the pilot-approved hardware, set it up, and provided training on the system's current functionality. Future functionality of the system and updates were provided via email and phone calls. Customer support was available to all participants during the entire length of the pilot via phone or email from Universal Devices. The SCE help desk was also informed about the pilot and provided with a contact person within SCE to help address any concerns that a pilot participant might have.

Storage Installation

Three pilot participants were selected to receive storage. Two of the recipients had a photovoltaic system, and one did not. The RATES team wanted to analyze both types of locations. The first recipient was provided storage by ElectrIQ, who provided the hardware, software, and installation services. The software did not provide the functionality promised by the vendor.

SCE was interested in exploring the benefits of storage with the RATES system. SCE decided to purchase and install three new storage solutions for three RATES pilot participants. After an in-depth analysis of the storage solutions available in the market, two solutions were selected: Outback and LG Chem. Universal Devices tested both systems with a remote connection. The RATES team ultimately decided that the LG Chem battery model RESU10H with SolarEdge inverters will be a better match due to its functionality, noise level, and exterior. All solutions were installed in residential venues, which affected the selection criteria (see APPENDIX B: Pilot Participation Verification and Deployment Memo).

Phase 1: Participant Facility Monitoring and Analysis

TeMix and Universal Devices developed systems to monitor the transactions and use of energy by each facility and for devices that had a Z-Wave controller with two-way communications with the ISY Portal.

The TeMix Agent Portal has a 24/7/365 dashboard that has red or green status buttons to indicate that a facility is functioning normally within RATES. The dashboard shows which facilities have been properly configured, registered for Green Button meter data feed, and had a subscription created for the subscription transactive tariff. The dashboard also monitors the ALSI, ADSI and California ISO interfaces.

The dashboard monitors when each facility receives hourly, 15-minute, and 5-minute tenders from the SCE LSE and any transactions that result from the tenders. The dashboard monitors when the five-minute ex-post balancing tenders are received, when the ISY Portal creates the five-minute meter reading, the ex-post transactions, and sends both to the TeMix Platform.

This dashboard monitors the operation of devices that are being managed on the ISY Portal. For example, for HVAC devices, the inside and outside facility temperatures, the thermostat heat and cool settings, preferred optimized setpoints, and status of the machine learning of the parameters of the HVAC in the facility are monitored.

Analysis of specific facilities and devices is routinely performed using the dashboard and other data to assure the performance and reliability of the end-to-end RATES system. The information was also used to continuously redesign the machine learning, optimization, and scarcity pricing formulas in preparation for Phase 2.

Phase 2: End-to-End RATES Operation with an Experimental Tariff

RATES has been in 24/7/365 Phase 1 operation for more than a year, including simulated management of customer devices such as HVAC. The HVAC machine learning is continuous, even if the device is not heating or cooling at the time. Transactions for the facility are continuously simulated. Control of devices by the agents requires only changing a flag on each managed device to operate according to the schedules and setpoints determined by RATES. Then the customer will pay bills based on the RATES agent's management of the customer devices and the customer's existing tariff. The advice letter approving the experimental tariff allows the RATES project to compensate customers so that effectively they pay as if they are on the subscription transactive tariff.

Technical and Non-Technical Barriers

Traditionally, there are barriers to using electricity prices to manage customer use of electricity to balance demand with supply. The barriers and this project's approach to each barrier are listed below.

Existing flat-rate, increasing block, and time-of-use tariff prices do not respond to granular time and locational grid conditions; there is no way around using granular time and locational prices. RATES addresses this barrier with tariff prices that are on five-minute intervals and can vary by transmission interface, circuit, and location on the circuit.

Real-time pricing is dynamic, but may not fully recover transmission, distribution, and generation cost. Either such prices are set ahead of each hourly or five-minute interval, or they are set after each interval; the RATES tariff provides forward and spot prices.

Broadcasting prices as an unlimited quantity kW tender may result in overreaction to prices and grid instability; RATES employs priced tenders for a limited quantity of energy to avoid overreaction to prices.

Pure real-time price tariffs may induce customer bill volatility and supplier revenue volatility; RATES also employs forward transactions and subscriptions to reduce bill and revenue volatility.

Fixed charges and demand charges reduce the portion of revenues from energy prices and dampen the price signal, thereby dampening the price response; The RATES tariff recovers fixed and variable costs in energy prices. More such costs are recovered using scarcity pricing when the grid is stressed.

The major technical challenges encountered, and actions taken are as follows:

- CISR forms caused major participant recruiting and project delays. CISR forms are used by customers to give authorization to a designated agent to access customer data. CISR forms and the meter data returned as a pdf by email could not be processed reliably. The forms were also intimidating for customers and thus a major barrier to adoption and progress on this pilot. The form was difficult for customers to complete. For example, the CISR requires a service account number. Many participants provided their customer number, which is different from their service account number. This and other issues would cause SCE to reject the form, and the customer would have to start over.

- Actions taken: CISR authorization and data feeds were replaced with extensive development of an automated interface to the SCE Green Button meter data system that is now working reliably.

- Some of the SCE smart meters (over 30 percent) for the customer volunteers were unable to profile the home area network (HAN) communications functionality. This meant that the RATES technology in the home and business could not communicate directly to the SCE smart meter via the HAN ZigBee communications process. While most of the meters did have the HAN capability, others had to be reported as inoperable back to SCE. This issue required multiple trips to each customer when the meter experienced this issue. Due to the multiple trips and the customer support requirements, the pilot timeline was delayed, and installation costs increased.

  SCE analyzed the problem (it was a specific version of the meter that was found to lack the HAN profile), and the recommendation to replace the original meters with HAN-enabled updated versions was decided as the remedy. The RATES team proceeded with the recommendation; however, the meter issue caused many delays within the project. The SCE meter group was made aware of this issue and expedited the replacement of these meters within two to three weeks. This meter replacement issue was also inconvenient to the pilot participants because it affected their billing cycle. Mark Martinez from SCE requested ongoing reports on the meters replaced, and the issue was resolved eventually so that HAN communications were established.

  - Actions taken: The team developed a system to use Green Button meter readings to estimate missing five-minute readings and validate readings on a delayed basis.

- The SCE Green Button System was in a preliminary stage of development early in the project. There was little or no documentation to support its application.
  - Actions taken: A consultant was hired who was one of the key authors of the Green Button standard. He provided memos and feedback to assist SCE in the development of its Green Button system.

- Once the project team got the system to receive and process the SCE Green Button data with hourly meter reads, SCE began transitioning from hourly to 15-minute meter readings caused several more months of delay. The Green Button SCE and RATES systems did not reliably operate until late in the project. These continuing changes in the SCE Green Button system and SCE's use of several nonstandard features caused considerable cost increases and project delays. Because the CISR forms were unusable and the SCE HAN access to the SCE meter did not work for several customers, the RATES team had no choice but to depend on the Green Button systems for historical and ongoing meter data.
  - Actions taken: The team with its Green Button consultant designed a system to automatically transfer hourly and 15-minute Green Button meter readings to the RATES database and work around nonstandard elements of the SCE Green Button system as SCE transitioned from hourly Green Button meter readings to 15-minute meter readings.

- In some cases, the difficulty in maintaining connections with the SCE smart meter will be a major barrier to future spread of RATES.
    - Actions taken: The RATES team has developed methods to apply RATES without 5-minute readings from the meter and to employ delayed 15-minute hourly Green Button readings for ex-post balancing and settlement.

      It should be noted that if SCE were the operator of the RATES ADSI, then RATES could directly access the SCE meter data management system, greatly increasing the reliability of the metering for RATES. This option was not made available for this pilot.
- For cybersecurity reasons, SCE could not provide an API for real-time circuit loadings and forecasts for the Moorpark circuits.
    - Actions taken: The team developed a simple forecasting system to simulate the real-time and forecasted circuit loading. In full installations of RATES, the cybersecurity issues can be resolved.
- Aesthetics matter: Potential participants were not willing to replace their Nest and Ecobee thermostats with the proposed Z-Wave thermostats.
    - Actions taken: As a workaround, Universal Devices implemented node servers in the polyglot cloud framework for Nest and Ecobee.
- Proprietary and unavailable APIs for certain devices especially, high-end pool pumps.
    - Actions taken: Customers would not replace their high-end pool pumps with Z-Wave pool pumps. Unfortunately, there exist many pool pumps that have no publicly available APIs. This is especially the case for high-end pool pumps (iAqualink and Jandy). Universal Devices reverse-engineered the APIs by screen-scraping the official app. This said, however, the solution was not reliable. There are currently no solutions for this problem without a mandate for all pool pump manufacturers to make their APIs publicly available. It must be stressed that the only requirement should be for the availability of their APIs and NOT the standardization of their APIs.

      Alternatively, cloud pool pump operators could receive RATES hourly, 15-minute and 5-minute tenders and operate the pumps to save customers money, and then report the transactions to the TeMix Platform. The team has developed this capability, but there was no time to apply it in this pilot.

Technical Advisory Committee

A technical advisory committee was formed to review this pilot at three distinct points of the project. The first meeting was during the project design phase, the second was before hardware installation, and the last meeting was after hardware installation was complete. The committee raised concerns and provided feedback at every one of the meetings. In the initial meeting, the feedback related to understanding and possibly improving the system, its functionality, and the various inputs it requires to function properly. In the second meeting, the feedback was mostly concern about the effect on the participants and the calculation of the electricity price. At the last meeting, the main feedback was regarding scalability. Can the system be scaled from 100 users to 100 million users? The committee's feedback was considered by the design team, and their concerns were addressed by the project team, including SCE. Details regarding these concerns are also all addressed within this report.

Below is a list of the committee members and their respective organization:

- Carl Linvill, Regulatory Assistance Project (RAP)
- David Holmberg, National Institute for Standard and Technology (NIST)
- Janice Lin, California Energy Storage Alliance (CESA)
- Jill Powers, California Independent System Operator (California ISO)
- Lydia Krefta, Pacific Gas and Electric (PG&E)
- Mark S. Martinez, Southern California Edison (SCE)
- Michael Burr and Peter Douglass, The MicroGrid Institute
- Robert Levin and Masoud Foudeh, California Public Utility Commission (CPUC)
- Rolf Bienert, Open ADR Alliance
- Walt Johnson, Electric Power Research Institute (EPRI)

CHAPTER 3: Project Results

RATES Operational Example Results

This section presents a small sample of operational results of RATES. The RATES platform retains tenders, transactions, meter readings, positions, and billing for analysis. For pilot participants, with their permission, RATES also retains operational data for devices so that the operation of their devices and their optimizing agents can be verified and improved.

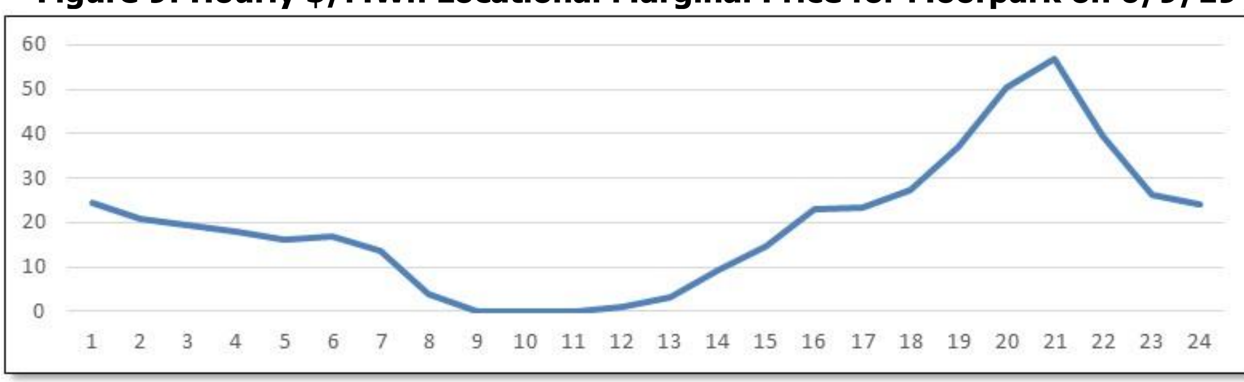
Tender Price Components

RATES uses granular scarcity pricing to develop the prices of the tenders for the SCE DO and SCE LSE. As described in Chapter 3, the concept is simple: recover more of SCE's fixed costs when the associated systems are most heavily loaded. The scarcity pricing curves described in Chapter 3, together with the actual and forecasted MW associated with each curve, determine the prices below.

Currently, there are four components to the delivered tender price. For Monday, June 9, 2019, the four components are shown below, followed by the bundled price (that is the sum of the four prices). The prices of all components and the bundled price vary considerably across all hours of the year.

The locational marginal price, Figure 9, is posted by the California ISO for each hour, 15 minutes, and five minutes. The LMP shown here is for the Moorpark transmission substation pricing node (pNode). The LMP drops from $25.00 per MWh during the first hour after midnight to near $0.00 from about 9 am to about 1 pm, and then increases to about $57.00 at about 8 pm before declining to about $24.00 at midnight. The low midday LMPs reflect the high solar generation MW at that time.

Figure 9: Hourly $/MWh Locational Marginal Price for Moorpark on 6/9/19

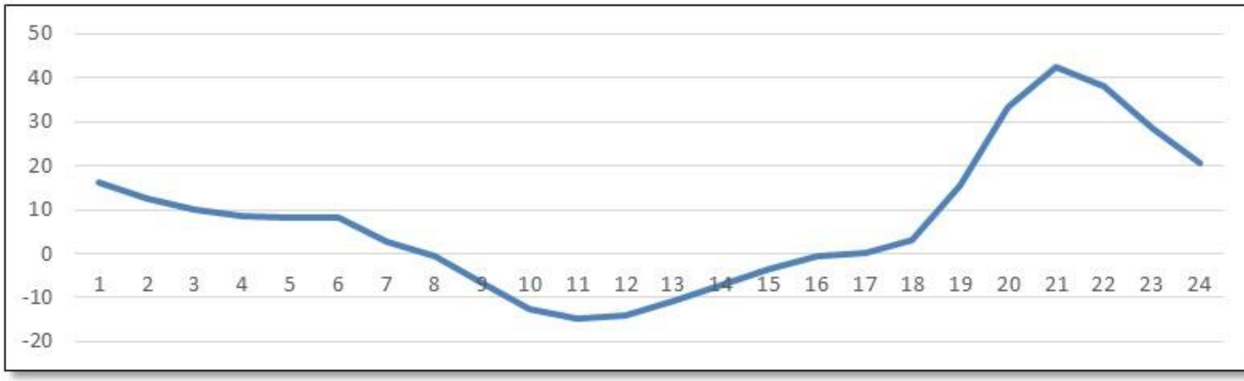


Source: TeMix Inc.

The recovery of the long-run marginal costs of bulk generation, as shown in pm.

Figure 10 begins the day at about $13.00 per MWh and declines to $0.00 at about 8 am, and then further declines to negative $14.00 from about 9:00 am to about 3:00 pm. The negative price reflects the cost of keeping the bulk generation available to be increased rapidly. Then the price increases to about $43.00 at about 9:00 pm.

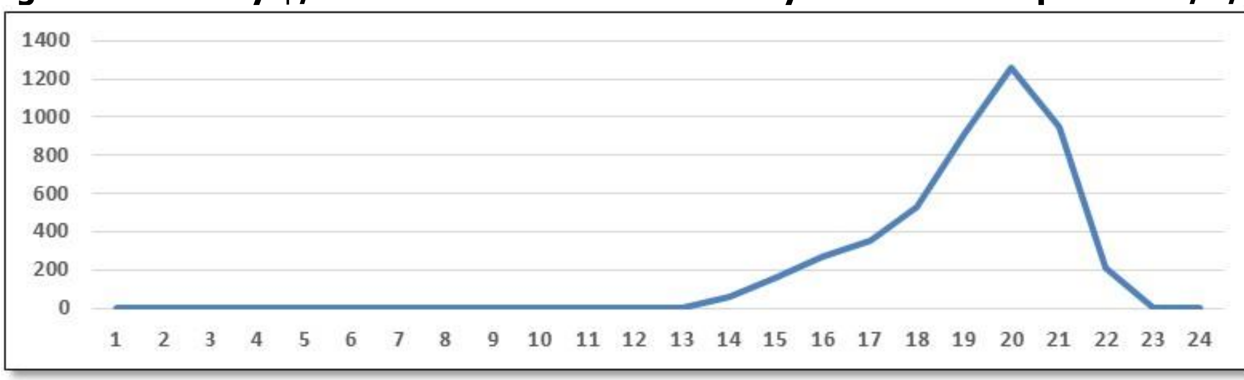
Figure 10: Hourly $/MWh Bulk Generation Scarcity Price for Moorpark on 6/9/19



Source: TeMix Inc.

The flex generation price in Figure 11 begins increasing at about 1:00 pm and peaks at about 8 pm at $1,263.00. The timing of this peak is affected by the greater number of hours of sunshine in June; in the winter, the peak would be earlier.

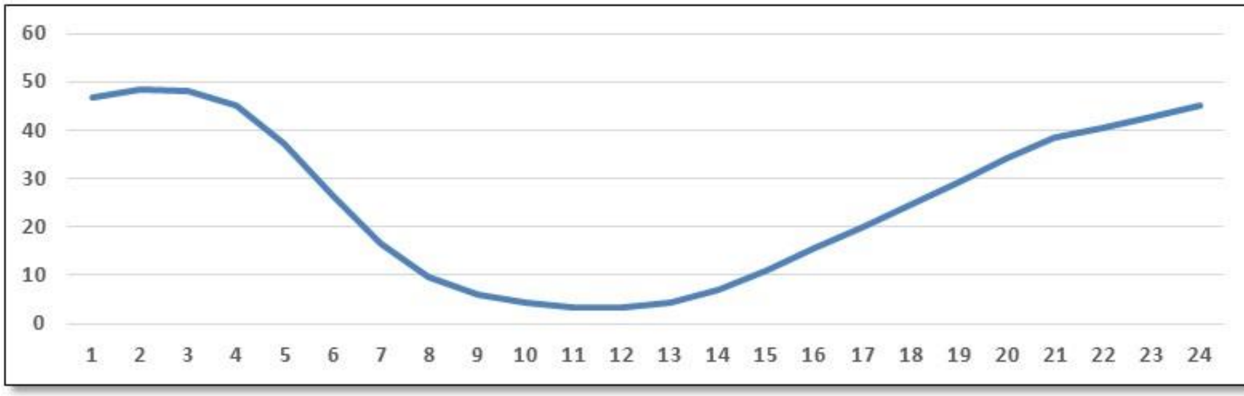
Figure 11: Hourly $/MWh Flex Generation Scarcity Price for Moorpark on 6/9/19



Source: TeMix Inc.

The delivery scarcity price in Figure 12 recovers the cost of moving the energy at the Moorpark pNode to each facility. The recovery of costs is lowest in the middle of the day when the production of solar energy on the Moorpark circuit almost offsets the midday usage of the customers on the circuit.

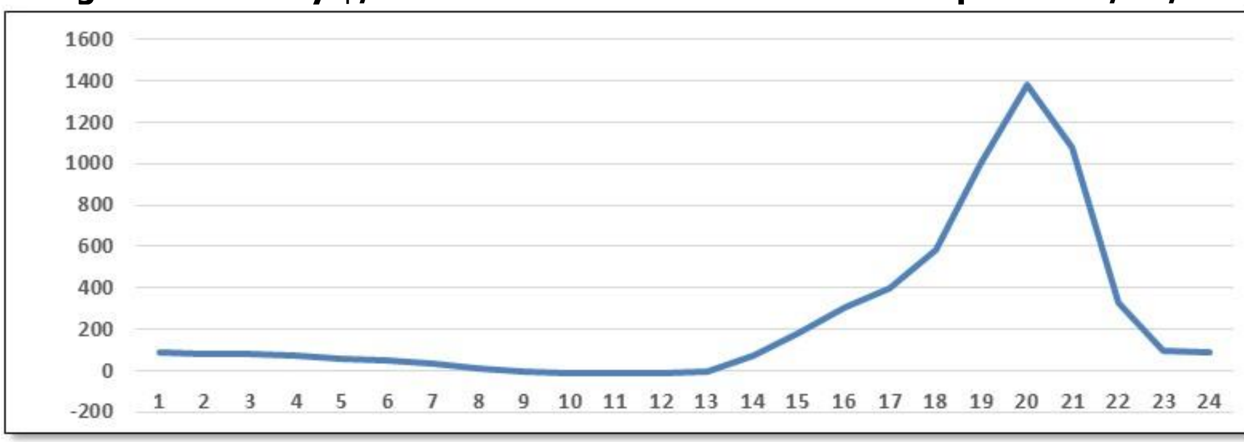
Figure 12: Hourly $/MWh Delivery Price for Moorpark on 6/9/19



Source: TeMix Inc.

Finally, in Figure 13, the total of the components is the bundled delivered price. The bundled price is about $82.00 at 1 am, declining to negative $11.00 at $11 am and then increasing to $1381.00 at 8:00 pm. Clearly, on this day, flex scarcity price is the dominant contributor to the bundled price.

Figure 13: Hourly $/MWh Bundled Tender Price for Moorpark on 6/19/19



Source: TeMix Inc.

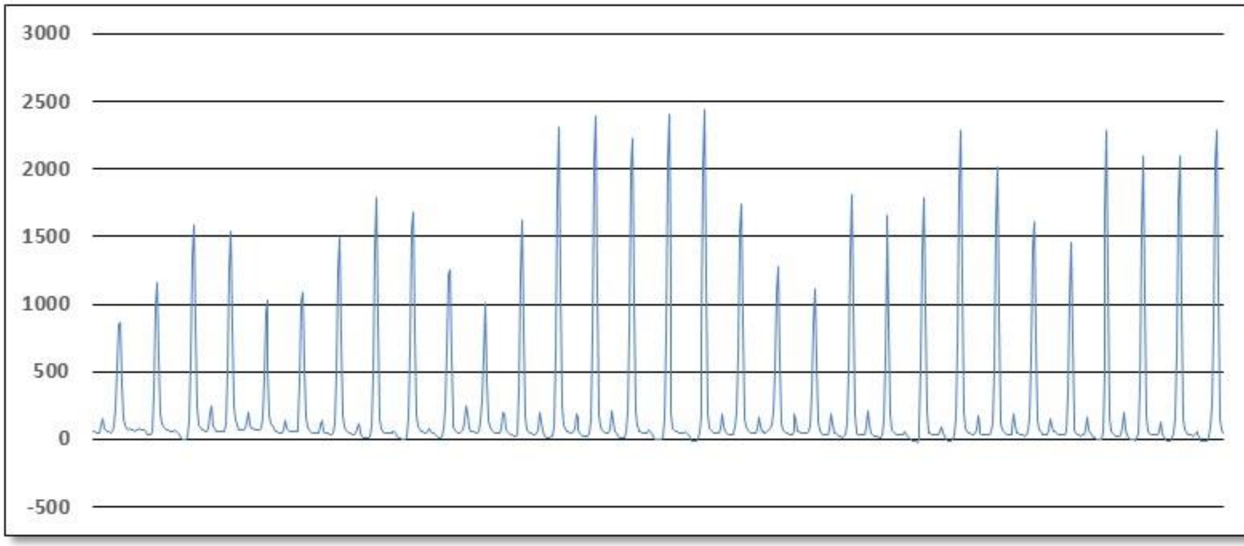
Bundled Tender Price Examples

The hourly bundled tender prices for Moorpark, as described above, are shown below for three selected months in 2019 in Figure 14, Figure 15, and Figure 16.

The three figures generally show a similar pattern for each day of each month.

Specifically, the March tenders show a secondary price ramp about 7 am most mornings, but other than the large evening ramp peaking at about 6 pm, there are generally low prices all day.

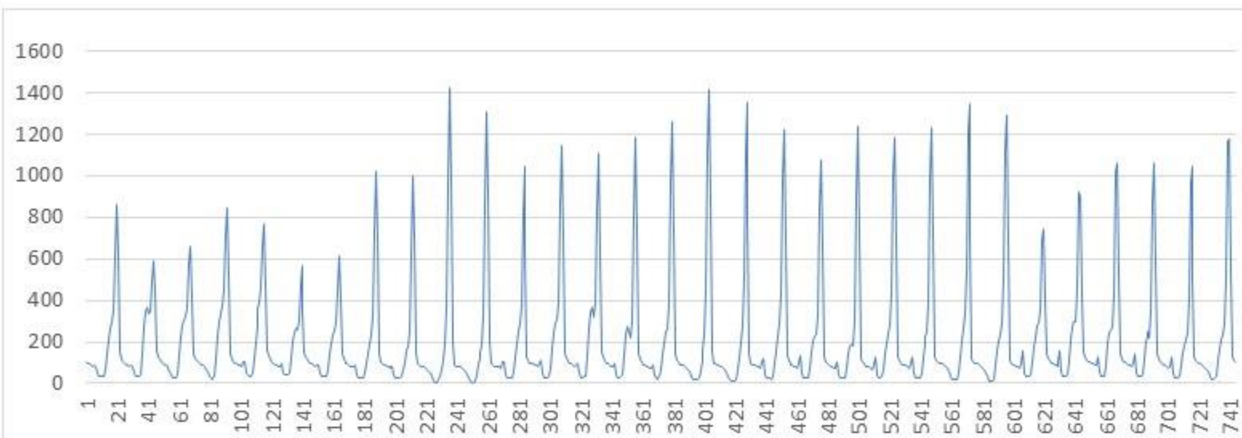
Figure 14: Bundled Tender Prices ($/MWh) for Moorpark for 31 Days of March 2019



Source: TeMix Inc.

The August tenders in Figure 15 also show a secondary price ramp at about 7 am, but the prices are higher all day. The evening prices do not ramp as high as in March because loads are higher during the day for air conditioning.

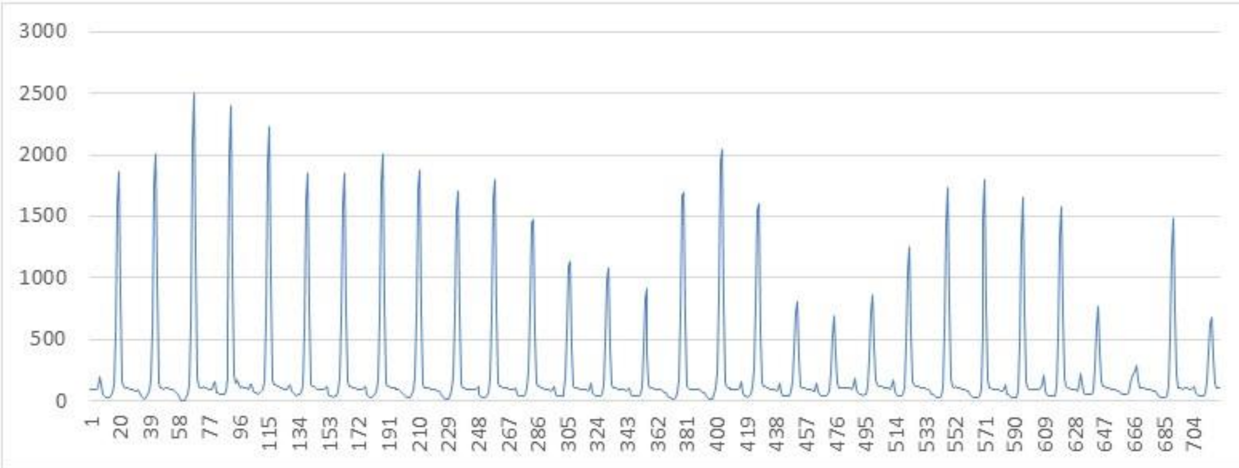
Figure 15: Bundled Tender Prices ($/MWh) for Moorpark for 31 Days of August 2019



Source: TeMix Inc.

The November tenders in Figure 16 have higher evening prices peaking at about 7 pm with a secondary morning ramp peaking at about 7 am.

Figure 16: Bundled Tender Prices ($/MWh) for Moorpark for 30 Days of November 2019

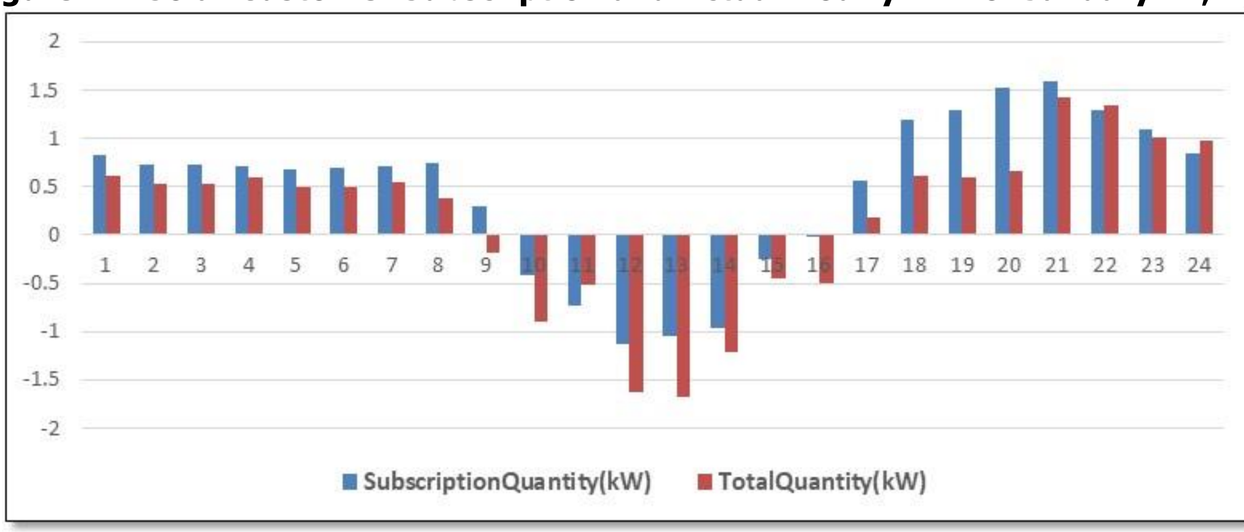


Source: TeMix Inc.

Experimental Tariff Billing for 24-Hour Day

Figure 17 shows the hourly net-metered kW of a solar facility for 24 hours of January 27, 2019. The actual net-metered kW is shown in red, and the subscription net kW is shown in blue, based on averaged historical meter readings. Since this customer has solar, the midday net kW can be negative, as shown in the figure. When red metered kW is less than the blue subscription kW, the customer sells the difference versus actual meter load.

Figure 17: Solar Customer Subscription and Actual Hourly kW for January 27, 2019

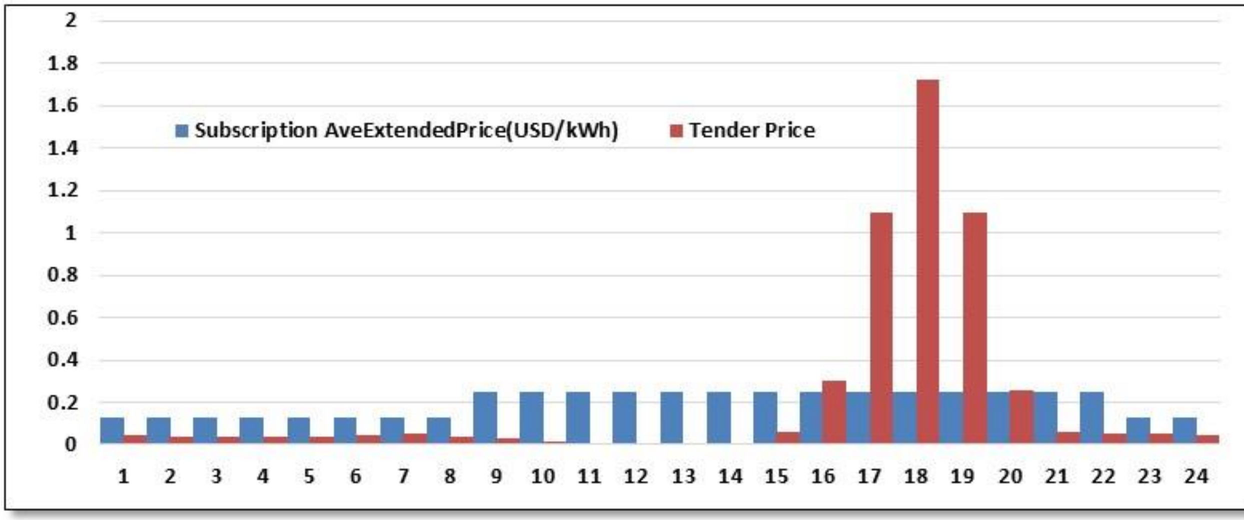


Source: TeMix Inc.

Figure 18 shows the hourly TOU Plan A prices (blue) for a customer and the hourly transactive tender prices (red). As of April 12, 2019, SCE has new TOU rate plans, and TOU Plan A has since been grandfathered. The new TOU SCE Rate plans were out of scope for this project.

The figure illustrates the large differences between the TOU and the transactive prices.

Figure 18: Time-of-Use versus Transactive Prices for January 27, 2019



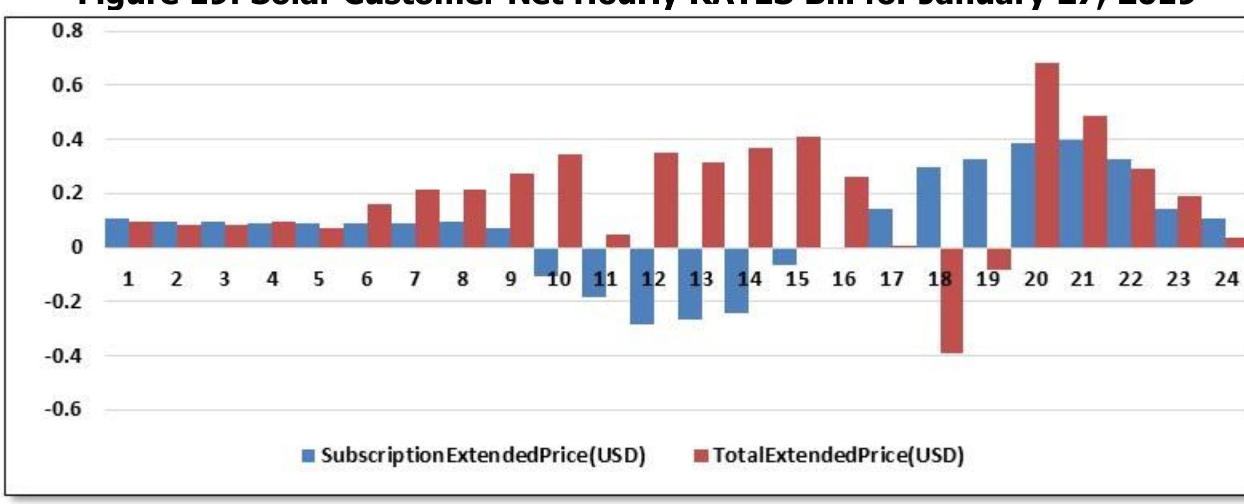
Source: TeMix Inc.

Figure 19 shows the net hourly cost (blue) of the subscription portion of the subscription transactive tariff and the total net hourly cost of the subscription and the transactions to satisfy the netload.

The net day cost of the SCE TOU tariff with net metering is $4.81. The net day cost of the RATES subscription transactive tariff is $4.62. In this case, there are slight savings to the customer with the subscription transactive tariff even before responding to the transactive tender prices.

Additionally, since the SCE and RATES net cost (bills) for the day are about the same, this illustrates that the RATES subscription transactive tariff retains the net metering benefit of higher midday TOU prices and high energy returned to the grid under the SCE tariff for this customer. This means if the customer can add flexibility using storage or other means, the customer will receive the full benefit of storage plus the preexisting net metering benefits of solar under their current SCE tariff.

Figure 19: Solar Customer Net Hourly RATES Bill for January 27, 2019



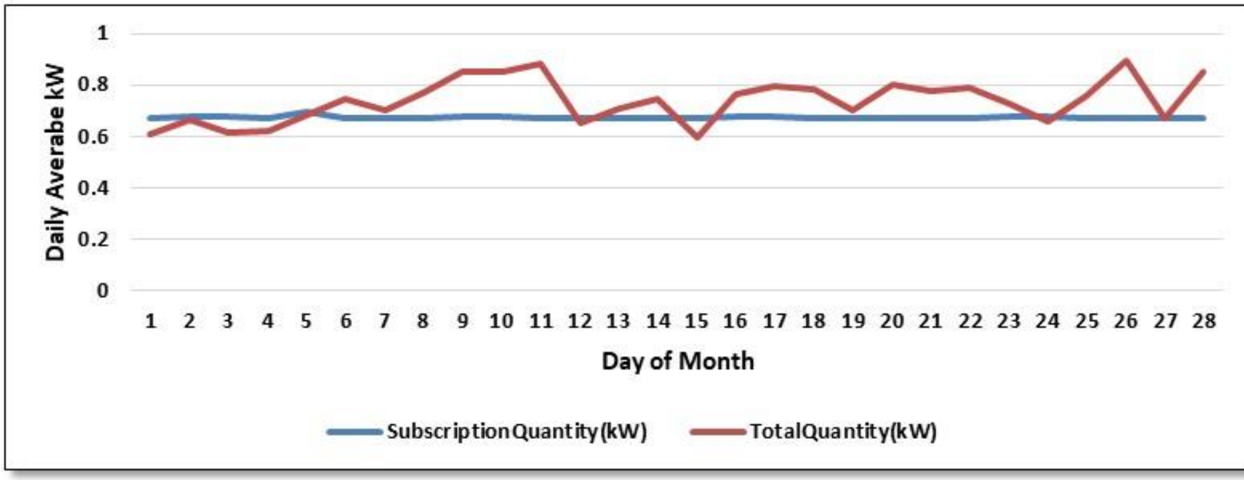
Source: TeMix Inc.

Experimental Tariff Billing for a Month

This example shows the SCE and RATES bills for the 28 days of February 2019 for the solar customer in the previous example.

Figure 20 shows in red the daily average kW quantity for a non-solar customer for each of the 28 days in February 2019. The daily low is about 0.6 kW (14.4 kWh), and the daily high is about 0.9 kW (21.6 kWh). The average kW for the month is 0.74 kW or about 17.76 kWh per day for the month, or 497 kWh total for the month. The figure shows, in blue, the subscription quantities of about 0.67 kW or, about 16.08 kWh per day.

Figure 20: Non-Solar Customer, February 2019 Daily Average kW



Source: TeMix Inc.

Figure 21 shows the 28 daily costs for the RATES bill for February 2019 for this non-solar customer.

Figure 21: Non-Solar Customer, February 2019 RATES Daily Cost

Source: TeMix Inc.

The RATES bill subscription cost component is in blue for the 0.67 kW average kW. The customer's original tariff is a tiered rate, where the cost increases when the total kWh reaches a tiered level. The daily subscription cost increases from about $3.00 per day for this customer to about $4.00 per day. The RATES bill subscription cost component for the month is $95.70 for 450 kWh (0.212 $/kWh).

The total RATES bills are shown in red, and the total bill for the month is $111.69 for 497 kWh (0.224 $/kWh). The SCE bill under the existing tariff (not shown) for the full month is $95.70 for the same 497 kWh.

With the experimental tariff, the customer pays the SCE tariff bill of $95.70 but would have paid $111.69, $15.99 more under the RATES tariff. This extra cost would subtract from the cumulative rebates for other months when the RATES bill is less than the SCE bill.

A key observation, for this customer, is that the SCE and RATES monthly bills are about the same despite the highly variable hourly spot prices during the month. Since this customer does not currently have any significant flexible devices during the winter (heating is not electric) and has no pool pump, no EV, and no battery, the customer will have to wait until warm weather to achieve a benefit from the automated, flexible response of the air conditioner.

Experimental Tariff Billing for Several Facilities for a Month

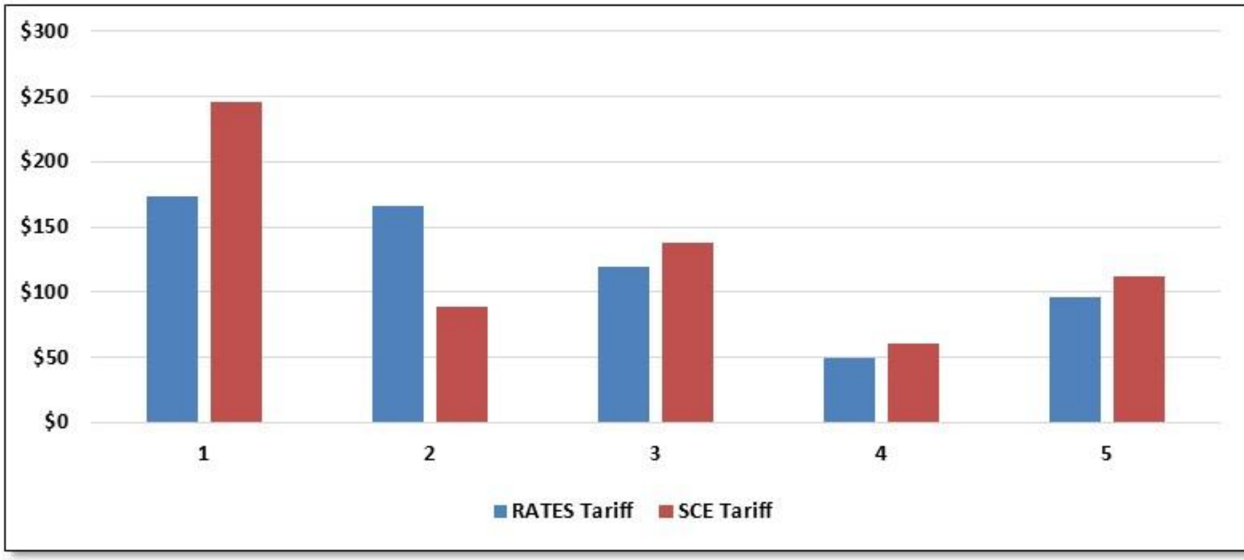
Figure 22 shows the RATES tariff bill (blue) and the SCE tariff bill for February 2019 for five sample customers. Four of the five customers have a RATES bill that is lower than the SCE bill. One customer (#5)—the customer analyzed in the previous two sections—has a RATES bill that is higher than the SCE bill. Customers #4 and #5 have solar.

The SCE bill and the RATES bill for a customer depend on many factors, such as weather and occupancy.

The RATES bills do not show the effect of the RATES tariff transactive prices on usage because, during February, none of these customers used air conditioning or other flexible devices.

Any conclusions about the relative volatility of the SCE bills and the RATES bills over a year will require more analysis of actual results, which was not possible within the project completion deadline of March 2019 and due to implementation delays, as explained elsewhere in this report. However, these results demonstrate the billing functionality of RATES.

Figure 22: RATES Bill and SCE Bill for Five Customers for February 2019



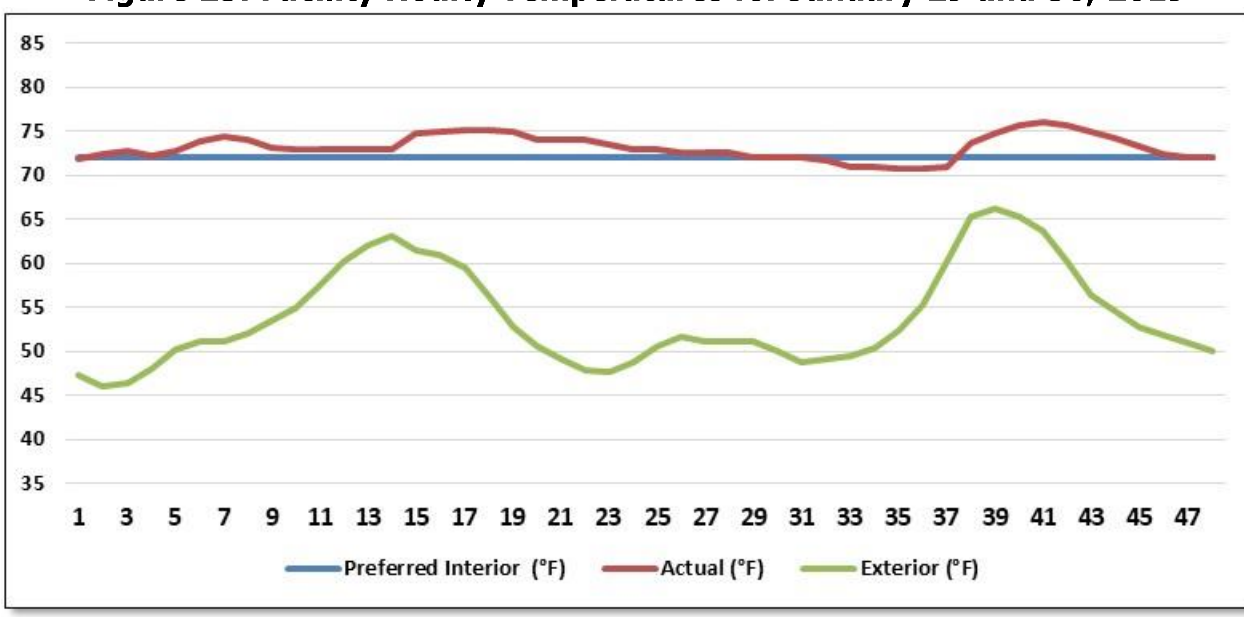
Source : TeMix Inc.

TeMix Agent Results

HVAC Agent

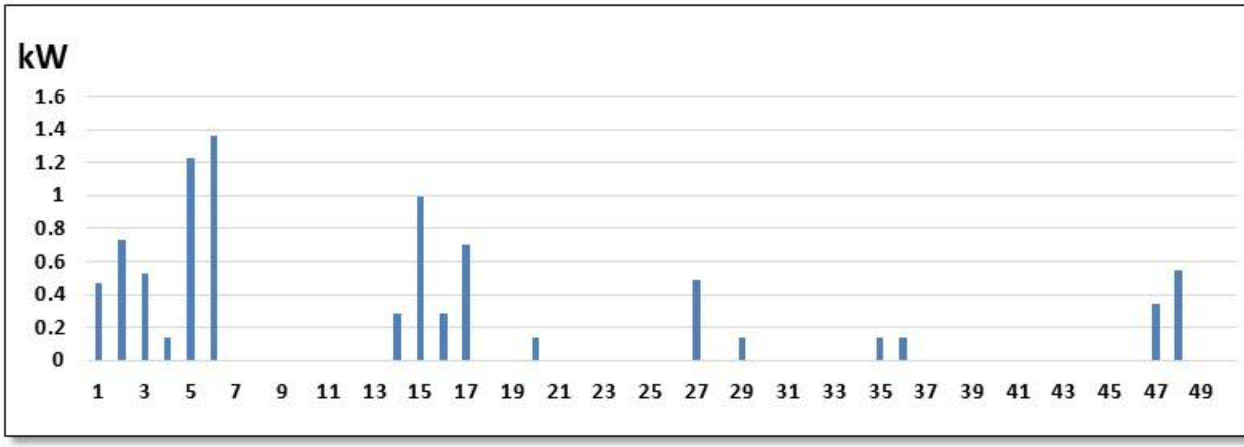
Figure 23 shows the agent's actual management of the thermostat in heat mode for an electric heat pump. Figure 25 shows the tender prices, and Figure 24 shows the hourly heating kW. All three figures are for 48 hours: the first 24 hours for January 29 and the second 24 hours for January 30, 2019.

Figure 23: Facility Hourly Temperatures for January 29 and 30, 2019



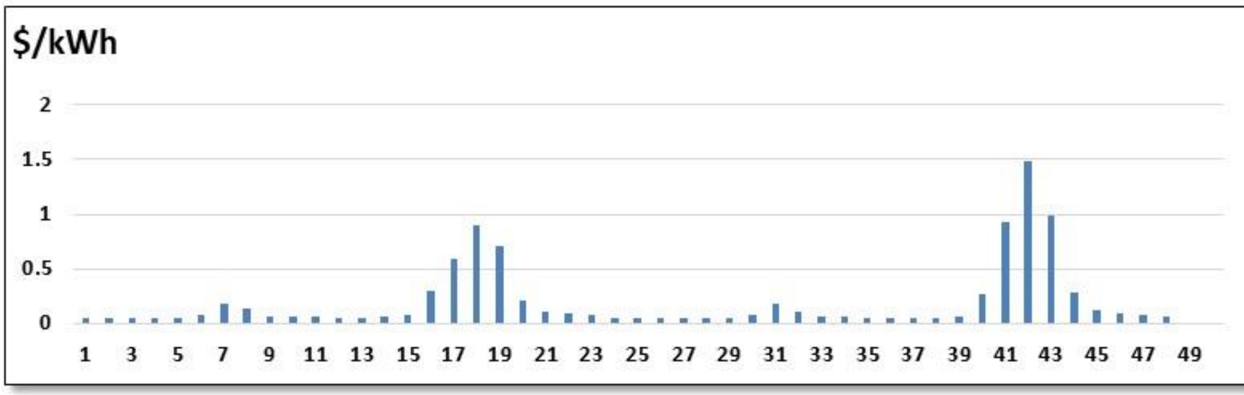
Source: TeMix Inc.

Figure 24: Facility Hourly Heating kW for January 29 and 30, 2019



Source: TeMix Inc.

Figure 25: Facility Hourly Tender Prices for January 29 & 30 2019



Source: TeMix Inc.

As can be seen, the exterior temperature ranges from 46°F (8°C) to 67°F (19°C). The preferred setpoint is 72°F (22°C) in every hour. The actual interior temperature varies below and above 72°F (22°C).

The tender prices shown in Figure 25 are highest at about 6 pm and have a secondary high at about 7 am each day. The HVAC, as a result of setpoints determined by the agent, avoids running when the tender prices are high.

On both days, just after noon, when tender prices are low and the exterior temperature is relatively high, the HVAC preheats in anticipation of higher tender prices and lower exterior temperatures.

The operation of the HVAC, in this case, is at a high comfort level as set by the customer. If the customer chooses a lower comfort level, the interior temperature level may vary more, but the cost to the customer may be lower.

In the cooling mode, the HVAC has the reverse behavior. For example, the cooling would likely not run during the evening price peaks that occur at a later hour in the summer. Moreover, the AUTO mode can be set by the customer where a heating and cooling setpoint are provided by the customer to manage the temperature within a defined range.

This response of an HVAC to tender prices, as illustrated here, when implemented at scale, should have a major benefit to the grid in terms of reduced investment in flexible generation, especially with 100 percent clean energy.

Pool Pump Agent

Table 1 illustrates the operation of the pool pump during each 24-hour day from January 9 to 14, 2019. When the cell is red, the pool pump is on for the full hour. The pump uses about 0.74 kW. The customer has asked for eight hours per day of pumping with up to two starts per day. The agent may run it one hour less or more in a day and catch up the next day if it saves the customer more money.

Table 1: Pool Pump Operation for Selected Days, January 2019

Hour	9	10	11	12	13	14
1	0.74	0.00	0.74	0.73	0.00	0.73
2	0.74	0.74	0.73	0.73	0.00	0.74
3	0.74	0.74	0.00	0.74	0.00	0.74
4	0.74	0.74	0.00	0.74	0.73	0.74
6	0.00	0.00	0.00	0.74	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.74	0.00
9	0.00	0.00	0.00	0.00	0.73	0.00
10	0.00	0.00	0.73	0.00	0.73	0.00
11	0.73	0.74	0.74	0.00	0.73	0.00
12	0.74	0.74	0.00	0.00	0.73	0.74
13	0.74	0.74	0.00	0.74	0.74	0.00
14	0.74	0.73	0.00	0.74	0.74	0.00
15	0.00	0.72	0.00	0.73	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.73	0.00	0.00	0.00
23	0.00	0.00	0.73	0.00	0.00	0.00
24	0.00	0.00	0.74	0.00	0.00	0.73

Source: TeMix Inc.

As shown in Table 1, the pool pump operation is different every day and avoids the morning and evening ramps. For most days, there are considerable midday hours of operation consuming solar-generated electricity, even though conventional wisdom might suggest running the pump during the night hours at lower TOU rates.

The hourly pool pump operation shown in the table is the actual operation. However, the planned operation before the start of the day is based on the then-available forward tenders. As these tenders expire and new tenders are received, the agent may change the schedule for future intervals; sell back what was previously purchased for a given hour and buy in a different hour if the changes will benefit the customer.

Typically, the customer will set and forget the automated pump operation, perhaps adjusting the pump operation required hours per day, seasonally. At any time, the customer can ask Energy Expert how much has been spent on pool pump operation in the previous hour, day, or 30 days, for example.

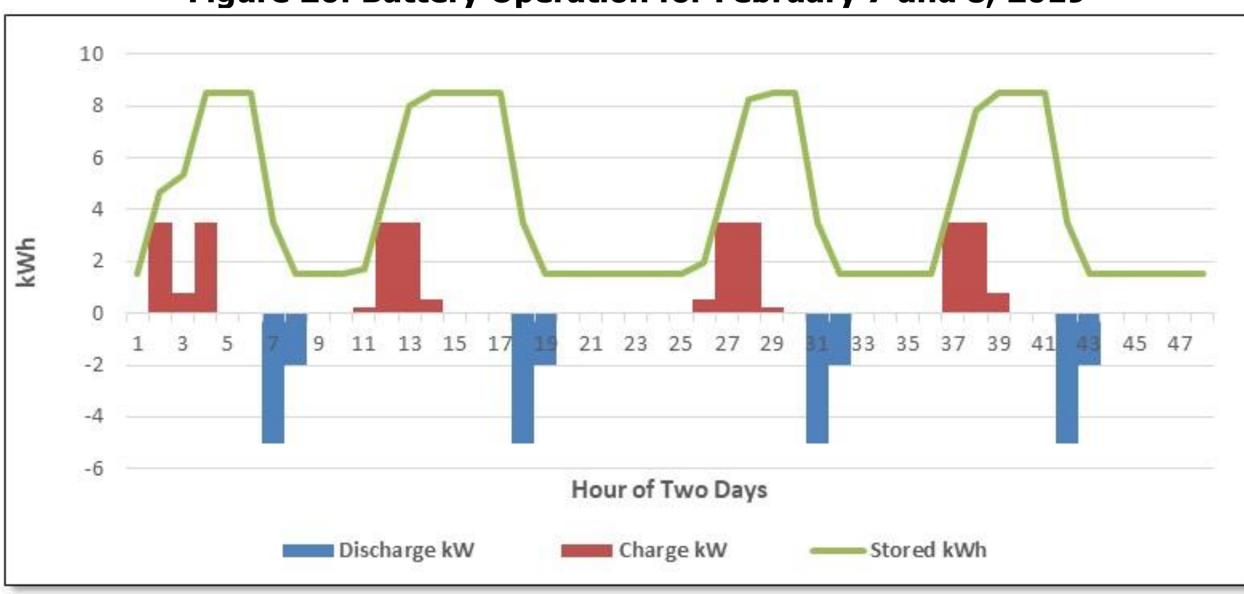
Battery Storage Agent

Shown in Figure 26 is the kW hourly charge, discharge, and the stored kWh over two days. Shown in Figure 27 are the tender prices for February 7 and 8, 2019.

This battery has a capacity of 9.8 kWh but is set to operate between 1.5 kWh and 8.5 kWh to reduce wear on the battery and provide some reserve kWh. The maximum discharge rate is 5 kW, and the maximum charge rate is 3.5 kW. The battery discharges, optimally, twice per day at about 6 am and 5 pm. It charges just after midnight and again around noon, with two round trips per day for the battery. The round-trip efficiency is 90 percent.

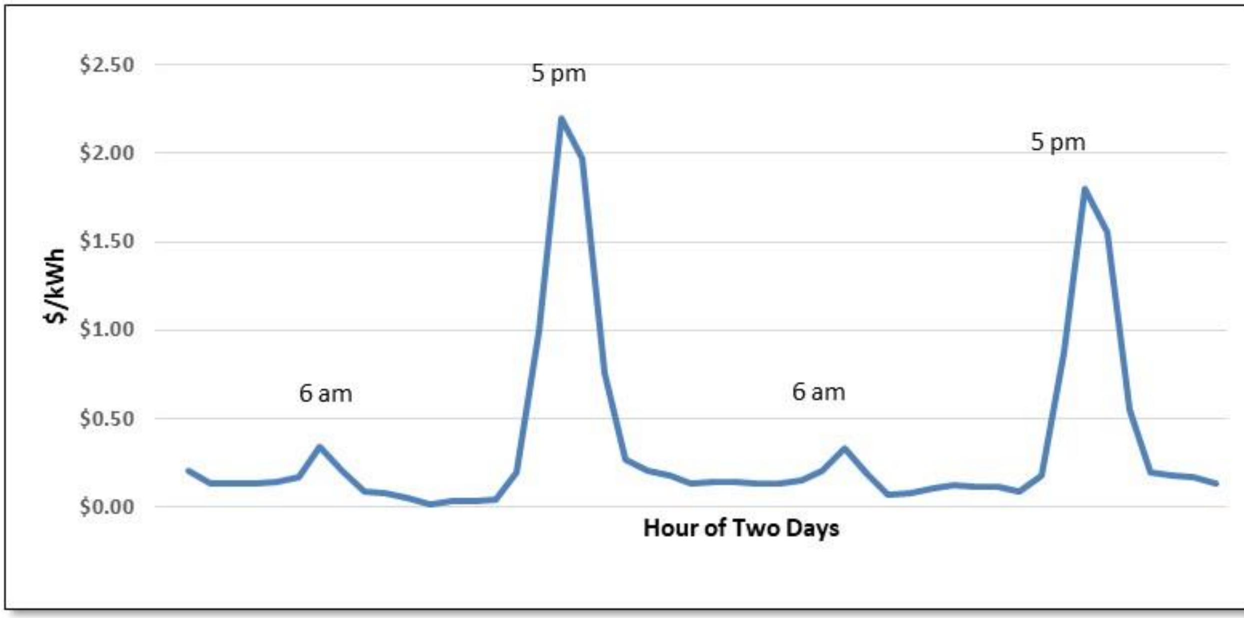
The net revenue for the battery is about $17.00 for the first day and $13.50 for the second day. The revenue includes wholesale, distribution (from reversing flow), and ramping revenues. Because of the scarcity pricing formula, capital and operating costs savings are included in the prices and daily savings.

Figure 26: Battery Operation for February 7 and 8, 2019



Source: TeMix Inc.

Figure 27: Tender Prices for February 7 and 8, 2019



Source: TeMix Inc.

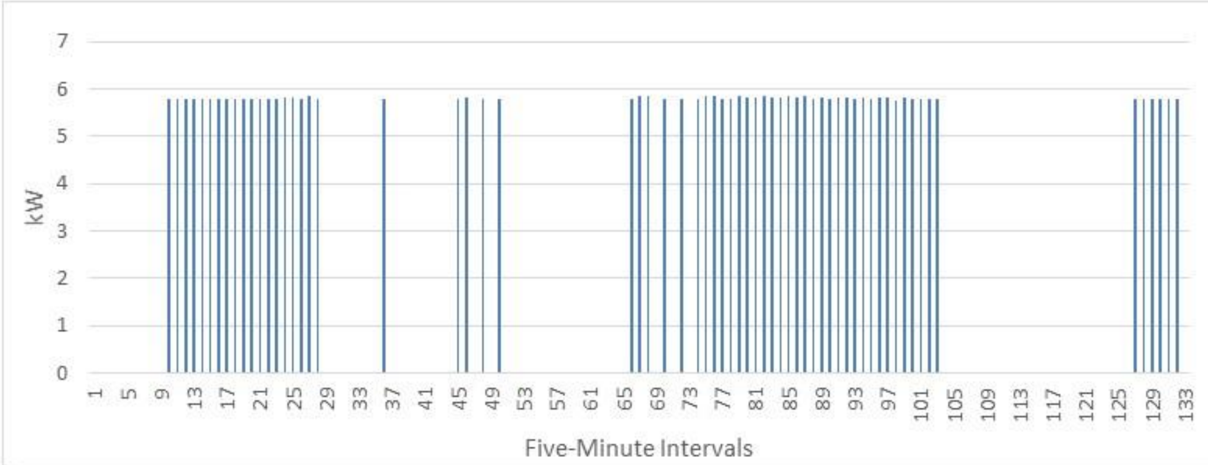
Electric Vehicle Agent

The electric vehicle agent typically minimizes the charge costs from the current SoC percent to the SoC percent requested by the owner by a given time. Shown in the figures below is an example charge for a Tesla Model S with a 100 kWh Battery (330-mile range) and a dedicated residential charger limited to about 5.8 kW. At 6:05 pm on March 6, 2019, the owner plugged the charging cable into the Tesla, and the EV agent automatically began optimizing the charging to achieve 75 percent SoC by 7:30 am the next day (about 13.5 hours), as requested by the owner.

Figure 29 shows the five-minute charge prices. Figure 28 shows the five-minute kW charge rate. Figure 30 shows the accumulating SoC percentage from 50 percent to 75 percent.

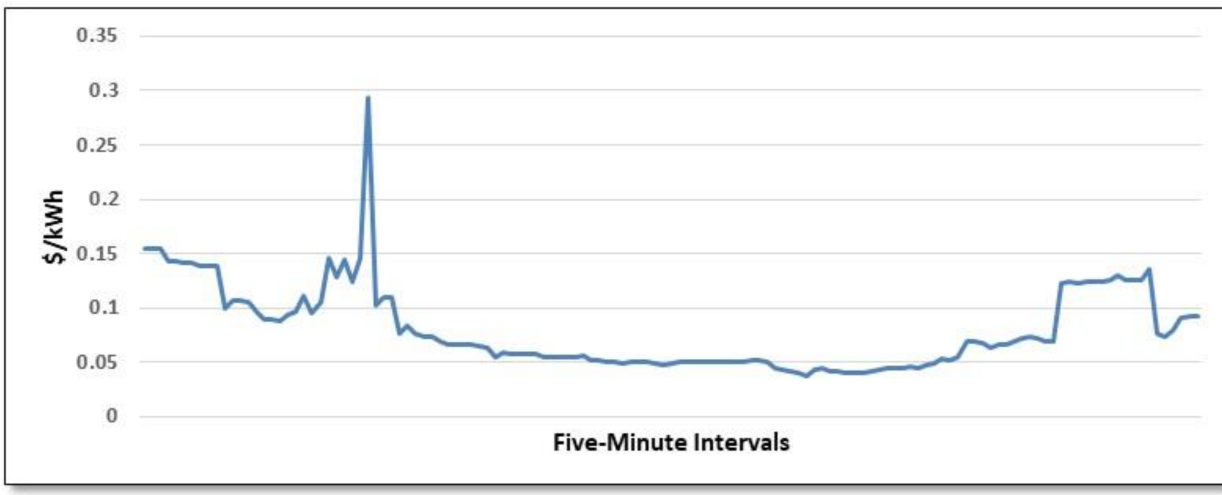
The total cost of the charge was $2.20. The charge added about 82 miles to the range at a retail cost of $0.027 per mile. Importantly, the agent easily avoids charging when the cost to the grid is high and benefits the customer by charging when the cost to the grid is low.

Figure 28: EV Five-Minute kW Charge: 6:05 pm, March 6, to 7:25 am, March 7, 2019



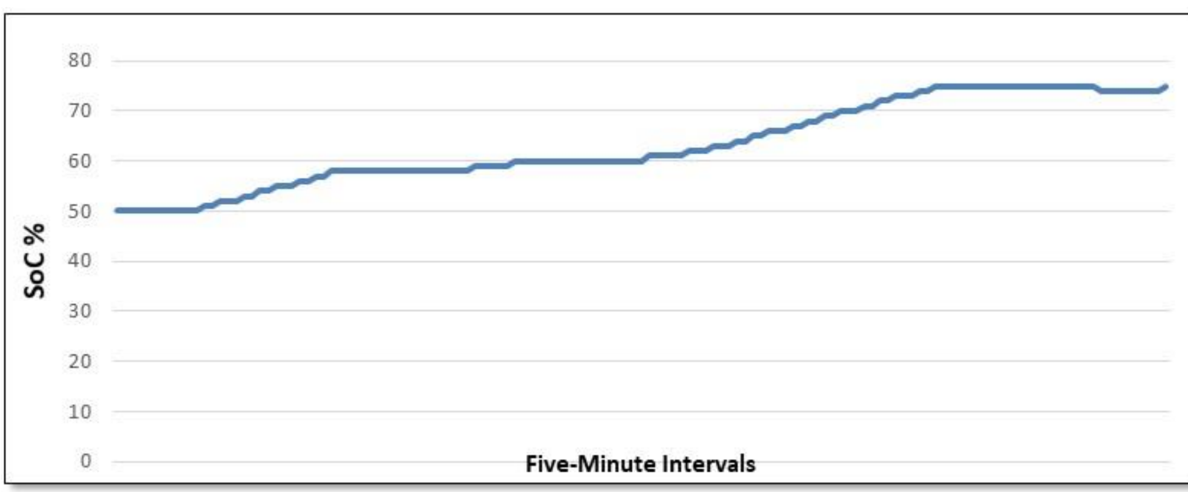
Source: TeMix Inc.

Figure 29: Five-Minute Tender Price: 6:05 pm, March 6, to 7:25 am, March 7, 2019



Source: TeMix Inc.

Figure 30: EV State-of-Charge from 6:05 pm March 6 to 7:25 am, March 7, 2019



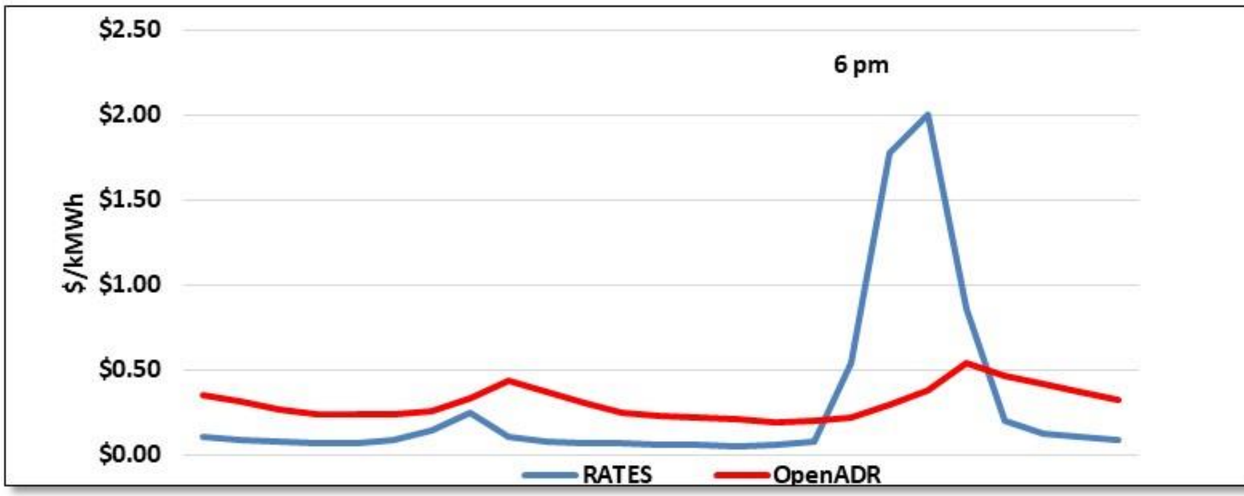
Source: TeMix Inc.

EPRI OpenADR Price Events

The EPIC grant for the overall CEC EPIC project required that this project also be able to receive and process OpenADR price events. The OpenADR price events are based on California ISO locational marginal prices times a multiplier of 3.62 to convert to retail $/MWh. The RATES prices use the California ISO locational marginal prices plus scarcity prices for delivery, generation fixed costs, and ramping fixed costs RATES tender prices.

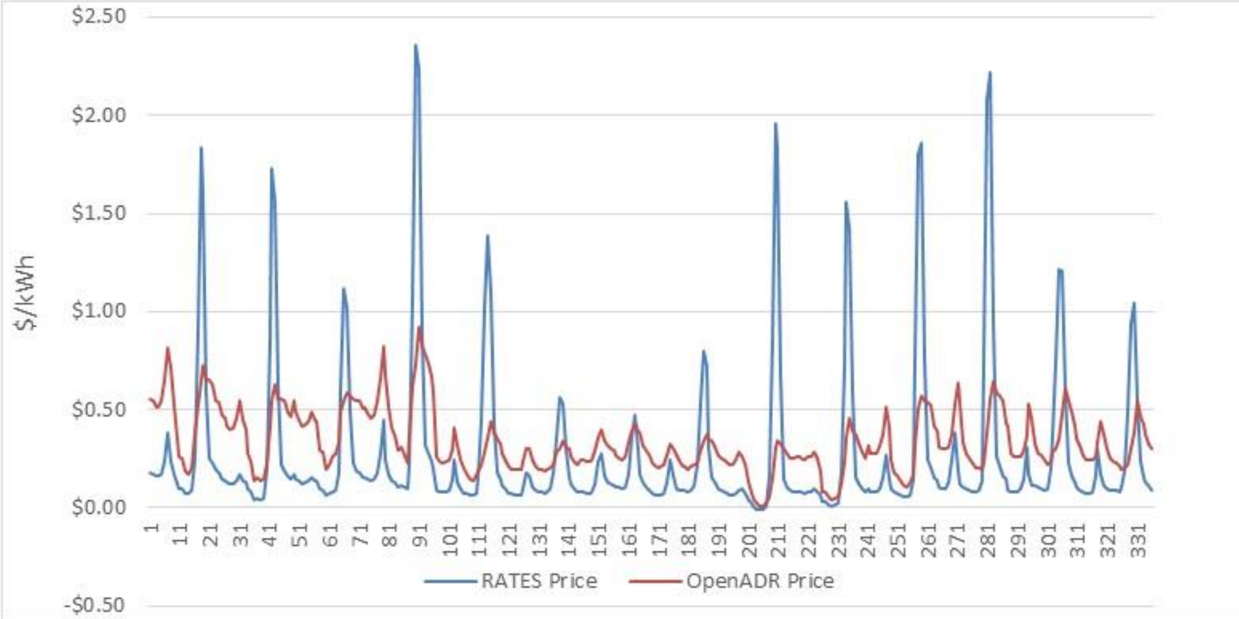
A comparison of RATES prices and the OpenADR prices is shown Figure 31 and Figure 32 below. The RATES prices are much lower when there is plenty of supply and much higher when there is a higher net load after renewables and higher 3-hour ramping for net loads. The RATES prices will therefore elicit more price responsiveness. The RATES tender prices are binding forward tenders that are updated hourly, whereas the OpenADR prices are indicative, nonbinding prices published once per day. The OpenADR Alliance has a working group in place to support binding RATES tenders and transactions.

Figure 31: RATES Tender Prices and OpenADR Prices for February 22, 2019



Source: TeMix Inc.

Figure 32: Comparison of RATES and OpenADR Prices for February 8 to 21, 2019



Source: TeMix Inc.

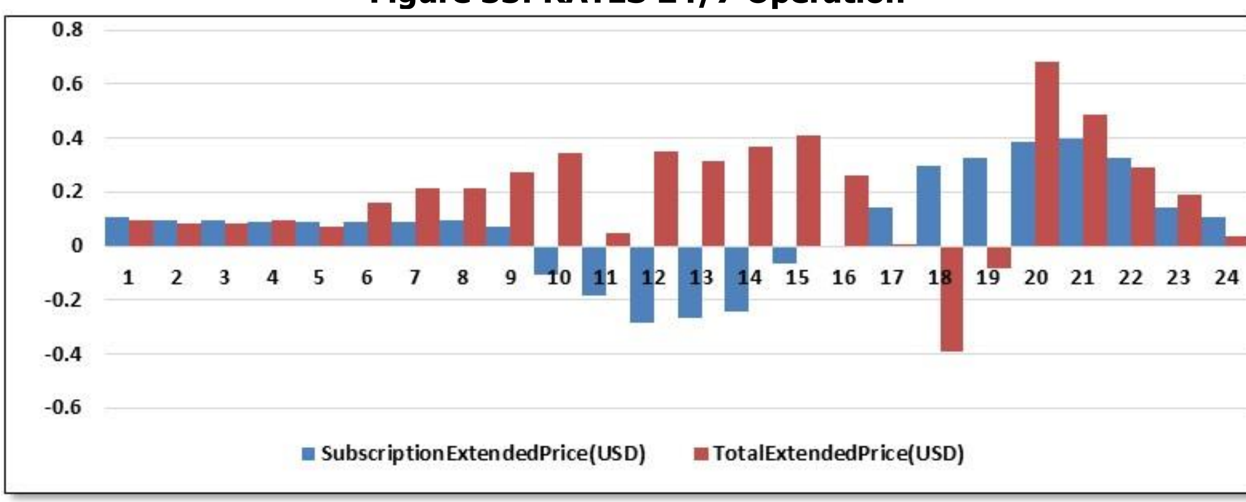
Project Achievements versus Project Goals and Objectives

The RATES project achieved what Universal Devices and TeMix were expecting and met the objective of the EPIC grant. Building on the existing Universal Devices ISY and the TeMix Platform, the team implemented the RATES design as proposed and installed it with about 100 retail customers on the SCE distribution grid.

RATES 24/7 End-to-End Operation

Since late 2017, RATES has been operating 24/7 end-to-end (California ISO to distribution operator to load-serving entity to retail customers and their devices) with return transactions and scheduling.

Figure 33: RATES 24/7 Operation



Source: TeMix Inc.

As is evident from the monthly progress reports to the CEC, during this period the team has continuously improved the algorithms used to manage customer devices, dealt with many hardware, communications, and software issues, learned about the customer and grid requirements by observing the customer's use of electricity and devices under widely varying weather and grid conditions during the year.

At a detailed five-minute level, RATES was interfaced with the California ISO and individual customers and their devices. The team demonstrated the feasibility of integration of wholesale and retail operations using a transactive system.

In this pilot, to stress test the end-to-end systems of RATES, the team has configured each facility to receive a full complement of subscription, hourly, 15-minute and five-minute tenders per hour. Tenders are inexpensive to create and communicate and need not be retained after they expire. Optimization is fast, and only about 10 percent of tenders result in transactions. Most of the communication traffic is for tenders. The settlement is also fast because each transaction quantity is multiplied by the price to get the transaction cost, and the bill is the sum of the transaction costs over a period, such as a month.

The tender payloads for the TeMix Web Services are shown in Appendix F:
The TeMix Platform Service Interfaces, and the TeMix Agent inputs and outputs are shown in APPENDIX G:
TeMix Agent. RATES can be configured with fewer tenders depending on the facility, but optimization is simpler with more frequent, small tenders.

Currently, the tender payloads are sent from the Microsoft Cloud TeMix Platform on the United States West Coast to the Amazon Cloud ISY Portal on the United States East Coast. One million facilities would use 20 GB per hour for tender communication, not a large volume in relation to millions of high definition video streams, for example.

Major Lessons Learned

As described in this report, RATES performs as designed. However, there are three major lessons learned concerning the application of RATES.

Requirement for More Robust Data Interfaces

The meter data for each facility (home or business) should be reliable and timely. The project team started with five-minute meter reads via the HAN interface to the SCE meter and the ISY. These were to be verified with hourly Green Button readings on a delayed basis (preliminary after a few days and final readings within a month). SCE is transitioning to 15-minute reads, which reduces the requirement for 5-minute meter reads. The California ISO operates on a 5-minute, 15-minute, and hourly basis.

Devices with Z-Wave, Wi-Fi, or other connectivity can be controlled and metered on five-minute intervals. However, the on-premise network and connectivity must be reliable and maintained. There were communications challenges within some homes that required extra effort.

After this pilot was completed in early 2019, at the end of 2019 SCE announced that it would not register new HAN connections to their meters after January 1, 2020. As described above, RATES without HAN-connected ISY five-minute readings will automatically operate on 15-minute Green Button communicated readings received about a day later. This will save on hardware, installation, and maintenance costs in the facility with a small loss in granularity and response time. Additionally, SCE could selectively change its metering interval to five minutes or shorter and provide earlier and more frequent meter data transfer to the TeMix Platform whenever the benefits are greater than the costs.

Access to real-time and forecast data on circuit load and SCE net load is needed from the distribution operator and the load-serving entity. The precision of these data is not critical because their use is only for RATES pricing and not direct control. More effort is required to access this load data automatically

The RATES interface to the California ISO is reasonably reliable but can be improved by working with the California ISO, distribution operators, and load-serving entities by integrating the interface with their scheduling coordinator operations.

Requirement to Interface with More Flexible Devices in Retail Markets

Most California homes have electric air conditioning and natural gas heating. In some areas of California, the climate is moderate, and air conditioning and heating loads are highly variable. In other areas, air conditioning loads are high in the summer but low in the winter. This project demonstrated that RATES could shift and shape air conditioning loads, taking account of the thermal storage in the building to the degree that is useful in heating season.

California plans to electrify residential heating. In this case, heating and cooling will be electric, such as from heat pumps, and can provide more year-round flexibility. This project demonstrated the flexible operation of heat pumps using RATES.

Residential battery storage is another source of flexibility that is now beginning to be used. Battery storage can provide 24/7 flexibility year-round. The RATES project developed the interfaces to operate residential batteries using RATES, but delays in purchasing and installing the batteries have delayed the demonstration of this capability.

Residential EV charging is another potential source of flexibility that is now possible in California. RATES has developed the capability to charge EVs flexibly and demonstrated flexible charging of Tesla EVs in a residential facility. The project has established two-way communication and dynamic control with Tesla EVs in residential facilities. EV charging is easily dispatched every five minutes or less using RATES.

Pool pumps offer a 24/7 source of flexibility, but most pool pump systems are now cloud-based and do not allow third party control; neither do they offer publicly available APIs for integration. The project developed the capability for pool pump cloud management systems to use RATES for managing the pool pumps in case the vendors would like to use this interface rather than making their APIs publicly available.

In summary, California electrification policy will result in large numbers of flexible devices for which RATES can enable self-management by customers to save money and reduce the cost of achieving California’s goal of 100 percent clean energy by 2045.

Requirement for Fully Operational Subscription Transactive Tariff and Platform

Without a fully operational subscription transactive tariff, customers and vendors will not have a reason to participate in RATES.

A subscription transactive tariff can now be implemented relatively easily, much more so than new time-of-use tariffs with fixed charges and associated demand response programs and baselines.

Each distribution operator and load-serving entity should proactively develop the formulas to determine the real-time transport and energy prices based on its costs and the locational marginal price inputs from the California ISO. Moreover, each distribution operator and load-serving entity should use the RATES platform to implement selected interfaces for each California ISO-connected distribution circuit. Customers can then be connected to RATES incrementally.

Future Work to Improve Knowledge Level and Technical Maturity

Valuable future work to improve the knowledge level and technology maturity of RATES should include the following:

- A RATES interface to the California ISO that directly supports real-time tenders and transactions at the wholesale-retail interface.
- Extension of the experimental RATES subscription transactive tariff to a formal optional tariff for retail customers by investor-owned load-serving entities and distribution operators. Training, pilots, and consulting support to the municipal, investor-owned, CCA, CPUC, and other entities may be necessary to improve their knowledge level of RATES and its applications.
- Validation and improvement of RATES' simple machine learning models for facility heating and cooling to address a wide range of facilities and their heating and cooling systems, including heat pumps.
- Pilots to jump-start use of RATES by other investor-owned utilities, municipals, and CCAs.
- Research on customer engagement with transactive energy systems and the role of aesthetics, AI assistants, IoT, and automation.
- A marketplace for developers to develop integration with any IoT devices that can then participate in a transactive energy ecosystem. This will provide incentives for developers and manufacturers to have APIs available without incurring much cost for developing or implementing their own agents to respond to tenders.

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

Approach to Build Market Adoption of RATES

RATES is a demonstration of transactive energy, which has been the subject of at least a decade of research and standards development. The approach demonstrated in this project is based on the TeMix model (Cazalet, Automated Transactive Energy (TeMix), 2011).

This pilot is the first, end-to-end implementation of the TeMix vision for transactive energy.

Target Audience for This Project

This research and the RATES product are intended for use by policymakers, regulators, investor-owned and municipal utilities, CCAs, California ISO, vendors of storage, energy management systems, home and business automation, and other electricity participants in the markets as described below.

Markets for RATES

The primary market for RATES is to distribution operators (investor-owned and municipal), load-serving entities (investor-owned, municipal, and CCAs), and ISOs. Additionally, other market participants will interface with RATES as retail participants or device vendors.

The Western energy imbalance market (EIM) covers a major portion of the Western United States. Current participants are Arizona Public Service, Idaho Power, NV Energy, PacifiCorp, Portland General Electric, PowerEx, and Puget Sound Energy. The California ISO operates the EIM; it is a straightforward project to apply RATES anywhere in the EIM footprint and with any EIM participant. RATES has great potential to improve EIM liquidity and benefits and participation by retail customers in the EIM.

Within California, every electricity entity and customer is a potential participant in RATES. A roadmap for the transition of California to transactive energy is available in Barrager and Cazalet, *51st State Roadmap, Sustainable Business, and Regulatory Model: Transactive Energy* (2016).

Near-term Target Markets for RATES

At the request of SCE, Universal Devices and TeMix submitted a proposal to SCE to apply RATES to three residential battery systems purchased by SCE, and SCE accepted this proposal. The RATES team will continue to examine the benefits RATES can provide using distributed energy resources such as storage.

TeMix is contracted with Polaris Energy Systems to provide RATES and other support to Polaris for a demonstration of transactive energy for agricultural pumping under their EPIC grant EPC-16-045. TeMix is also partnered with Lawrence Berkeley National Laboratory, Irrigation for the

Future, and Polaris Energy Services in a proposal to SCE for a "Feasibility Study and Pilot Demonstration of a Retail Automated Transactive Energy System for Agricultural Loads."

Mid-term Target Markets for RATES

The RATES team continues to provide webinars to various utilities and encourage additional utilities, especially SCE and other California IOUs, to examine the benefits that the RATES system has to offer. Following outreach activities, PG&E requested a pilot proposal from the RATES team. Universal Devices and TeMix are in discussion with several parties to use RATES in other U.S. states. The pilot team is exploring opportunities to include the transactive energy protocols in industry standards such as Open ADR. Lawrence Berkeley National Laboratory is also expressing interest in the Energy Commission exploring transactive energy and potential further grants.

Long-term Target Markets for RATES

RATES and transactive energy are applicable around the world. Barrager and Cazalet published a book in 2014 entitled *Transactive Energy: A Business and Regulatory Model for Sustainable Energy*, published in English, Chinese, and Japanese. Transactive energy and RATES can be a key element in California's advocacy of clean electricity on a global scale.

California Target Market Sizes

The target market for RATES is every load-serving entity and distribution operator in California and the California ISO. Additionally, direct access customers can participate in RATES. The California retail electricity market is approximately 41 billion dollars per year. (

Source: EIA). Fully operational in California, a fee of about 0.10 percent or about 41 million dollars per year would support RATES operations and staffing. The average retail cost of electricity is about $0.159 per kWh, and a 0.10 percent fee would be about 0.00016 per kWh. A customer with a $150 per month bill would pay about $0.15 per month for RATES. It is likely that this cost will be recovered by the distribution operators and load-serving entities from small differences between the buy and sell tender prices.

The above cost estimates would include the RATES cloud systems at scale, communications and settlement/billing calculations, and associated staff but not investment by participants in automated control and energy use, production, storage, metering and distribution, and transmission systems.

Promotion of RATES by Universal Devices and TeMix

Universal Devices and TeMix have engaged in the following activities to promote and accelerate the adoption of RATES:

- TeMix and Universal Devices have made presentations on RATES to Google and NEST.
- TeMix made a presentation to staff at the CPUC. This presentation set the stage for SCE to file the RATES tariff pilot advice letter with the CPUC.
- TeMix made several presentations on RATES to PG&E top management and staff and, as a result, was invited to submit a proposal for a PG&E RATES pilot.

- TeMix made a presentation on RATES to the STRATTON REPORT Grid 2.0 Symposium Series on January 11, 2017, in Sacramento to a broad audience.
- TeMix made a lengthy presentation on transactive energy and RATES for a second Grid 2.0 Symposium event in Mountain View, CA on February 21, 2017. The audience included a wide range of major Silicon Valley companies, consultants, utilities, and CCAs.
- TeMix made an invited presentation on RATES to the CEO of the Silicon Valley Clean Energy CCA.
- TeMix presented a webinar on transactive energy and RATES to a utility audience invited by the Edison Electric Institute.
- TeMix presented RATES at the 2017 annual meeting of the Smart Electric Power Alliance (SEPA).
- TeMix prepared descriptions of the RATES project for several SEPA newsletters and publications.
- Universal Devices presented RATES in an OpenADR Alliance member meeting in Sacramento, CA in April 2018.
- Universal Devices presented RATES in an Association of Energy Services Professionals meeting in January 2019 in San Antonio, TX.
- TeMix presented RATES on a panel at the EPIC 2019 symposium in February 2019. Universal Devices presented RATES in the poster session at the symposium.
- Universal Devices presented RATES at the Lawrence Berkeley National Laboratory in February 2019.
- TeMix presented RATES, by invitation to the Transactive Energy Working Group of SEPA on March 1, 2019.

Plans to Continue with RATES Commercialization

TeMix is currently enhancing the performance and security of the TeMix platform and agent to offer it as a commercial product for use by RATES and other applications. Emphasis is being placed on the capability to scale to many millions of facilities.

Universal Devices is continuing to refine its platform and services and, especially, Alexa's Energy Expert skill and Polyglot IoT layer. Universal Devices will be advocating transactive energy services as an OpenADR alliance profile.

Universal Devices and TeMix have worked with the OpenADR Alliance toward their goal of including transactive energy protocols, as used in RATES, in OpenADR.

Role of the Project in Simulating RATES Applications and Identification of Barriers or Challenges for Commercialization

The primary barriers to full installation and commercialization of RATES are misperceptions about transactive energy and support for centralized solutions for retail markets that can be overcome with effort and some time.

Parties supporting renewables and storage have the most to gain from RATES because it can fully monetize their benefits. However, some parties are still hoping that some form of retail participation in the California ISO spot markets through aggregation will provide additional revenues. Many of these participants are beginning to realize (1) that such aggregation is very complex, and (2) does not provide mechanisms to coordinate and reward behind-the-customer-meter, distribution-connected and transmission-connected storage with the full retail and wholesale benefits of storage.

Some parties see transactive energy as unregulated, unstable, and unfair. RATES remains regulated, and approved scarcity pricing formulas are used. RATES is designed to use forward and spot (real-time) transactions and tenders that are binding to minimize the role of market instabilities and to allow management of stability as necessary by adjusting maximum tenders' sizes and frequency of tender publication. Long-term subscriptions to disadvantaged customers can be offered at discounts to implement legislative policies on fairness.

Information from the RATES Project for Policy and Regulatory Actions

This project demonstrates the technical feasibility of transactive energy for California and anywhere. For California, RATES is a solid foundation for the California electricity market in an era of increasing renewables, electrification, and regulatory change. RATES builds bridges between regulated transmission and distribution, wholesale energy markets, and various retail business model, including more customer ownership of generation and storage. APPENDIX D: Policy and Business Use Case Report provides context for policy decisions regarding RATES.

The next steps are for distribution operators and load-serving entities to offer subscription transactive tariffs as an option to all customers. The tariffs, transactions, scheduling settlement, and billing calculations can be hosted on RATES at very low cost in comparison to current systems and installed incrementally by customers, regulators, utilities, and others as they gain understanding and confidence in RATES.

The CPUC likely has the authority to approve RATES tariffs for the IOUs without additional legislation, especially if the tariffs are opt-in, and the subscription transactive tariff is calibrated to recover currently approved costs of service and allocations of the costs. However, legislation could provide important policy direction to the Energy Commission, the CPUC, the California ISO, and load-serving entities and other market participants.

An important policy decision is who should host the RATES platform and how should its continuing operation, development, and oversight be organized. There are two basic options and many variations:

- A not-for-profit company is formed by the CEC, California ISO, or the Legislature. A Board is formed to oversee RATES, hire management and staff, and perform ongoing oversight. Companies such as TeMix and Universal Devices would contract to provide services to this public company.
- A private company such as TeMix hosts the RATES platforms and contracts with entities such as distribution operators. Load-serving entities, including CCAs, contract with TeMix for RATES services. The CPUC and CEC provide oversight under existing rules.

- In either option, the price spread between buy and sell transactions may recover some of the costs of operation. Otherwise, a small fee could be assessed on all retail loads.

If the state chooses the second option, then it will largely foreclose the first option for California, as it did in 1998 when it granted a monopoly to the public power exchange over at least two private exchanges.

APPENDIX D:
Policy and Business Use Case Report describes California policy history relevant to transactive energy and RATES.

Finally, the California electricity sector is in continuous institutional transition. Increasing numbers of CCAs, more direct access, a potential restructuring of PG&E, and sale of assets are under consideration. Whatever the outcomes of this transition, a RATES installation could be used by any electricity entities to provide mechanisms for efficiently coordinating transactions among the entities.

CHAPTER 5: Benefits to Ratepayers If Technology Were Commercialized

Importance of RATES to Ratepayers

California is committed to a clean energy electric grid and the electrification of transportation, buildings, and other sectors using clean energy. This transition will require ratepayer and non-ratepayer investment, for which ratepayers eventually pay. Such investments should be coordinated and not wasteful of energy and money. It is also important that customer energy-using and producing devices, including storage, be operationally coordinated with wholesale solar, wind, storage, and other generation.

The RATES platform offers the potential for coordination of most retail and distribution investments and operations with wholesale and transmission investment and operations. Operations are coordinated at hourly, 15-minute, and 5-minute granularity via locational transactive tariffs that recover costs in a way that reflects scarcity and abundance of energy. Each party responds to these priced tenders, and the resulting operational supply and demand influence the wholesale and transport prices, thereby continuously coordinating supply and demand.

Investments can be coordinated by years-ahead tenders and transactions in the same way operations are coordinated by spot tenders and transactions. The load-serving entities, distribution operators, or third parties would be market makers in these forward markets hosted on RATES. This project considered such long-term transactions as out of scope.

How Will Ratepayers Benefit from RATES?

Ratepayers (electricity customers) will benefit from RATES in several ways:

- Opportunities to reduce bills through better energy management, informed and automated by RATES.
- Increased bill stability with electricity subscriptions.
- Targeted subscriptions for low-income customers and fairness.
- Opportunities to monetize the flexibility of grid services for energy management, smart appliances and controls, storage, and solar technologies, including heat pumps, space conditioning, and water heating.
- Opportunities to reduce the cost of electric vehicle charging for the customer.
- Reduced costs of billing through RATES billing automation.
- Increased transparency for the customer in energy use and costs.

Adaptation of RATES to Other Retail Electricity Customers and Costs

Any business or resident can use RATES as currently designed. The basic RATES platform costs were estimated above at about 0.25 percent of a customer's bill, excluding control and communications systems.

For business, residential, agricultural, transport, and other customers who adopt the Internet of Things to manage, control, and maintain devices via the internet for a wide range of reasons, interface to RATES to receive and act on tenders should be required. This would mean that the incremental cost per facility of adopting RATES would be minimal at the scale of millions of facilities.

Potential Money, Energy, and Emissions Savings from RATES

For California, emissions will be primarily policy-driven to essentially zero by 2045. Electrical energy use is likely to increase substantially as a result of a shift to less use of natural gas and more use of clean electricity. The potential savings from RATES in this context, in the long run, will be monetary as a result of lower investment and more efficient operation of the grid. The assumption is that policy will drive greenhouse gas emissions to the low targeted levels.

Another benefit of RATES is increased customer management of their energy use and investment, helping them to achieve customer benefits and bill reductions.

RATES can replace much of the retail billing and transaction systems now in use. Since the current systems are typically not fully dynamic, they must be modified or replaced. The RATES system can handle a wide range of tariffs at a much lower cost than conventional transaction and billing systems.

Cost of RATES at Scale

As discussed in the report, there are several ways to install RATES, depending on the customer and other factors.

There are three basic installation cases at large scale of one million participants or more:

- ISY with HAN interface, with immediate five-minute metering: $125 per customer for ISY with Z-Wave.
- ISY with no HAN interface, with delayed 15-minute metering: $100 per customer with Z-Wave.
- No ISY, with cloud software device agents and cloud management of devices with delayed 15-minute metering: $25 per customer.

Maintenance cost is estimated at 15 percent of the above cost per year. Any at-scale use of RATES would likely be some combination of the above three cases.

Communicating thermostats, pool pumps, electric water heaters, EVs, and appliances that will be part of any solution should be an element of state policy for new equipment. Moreover, the incremental cost of voice assistants such as Amazon Echo and Google Home will likely be zero because most customers will have such voice systems for many purposes beyond RATES, and because Amazon and Google are rapidly lowering the prices of such systems.

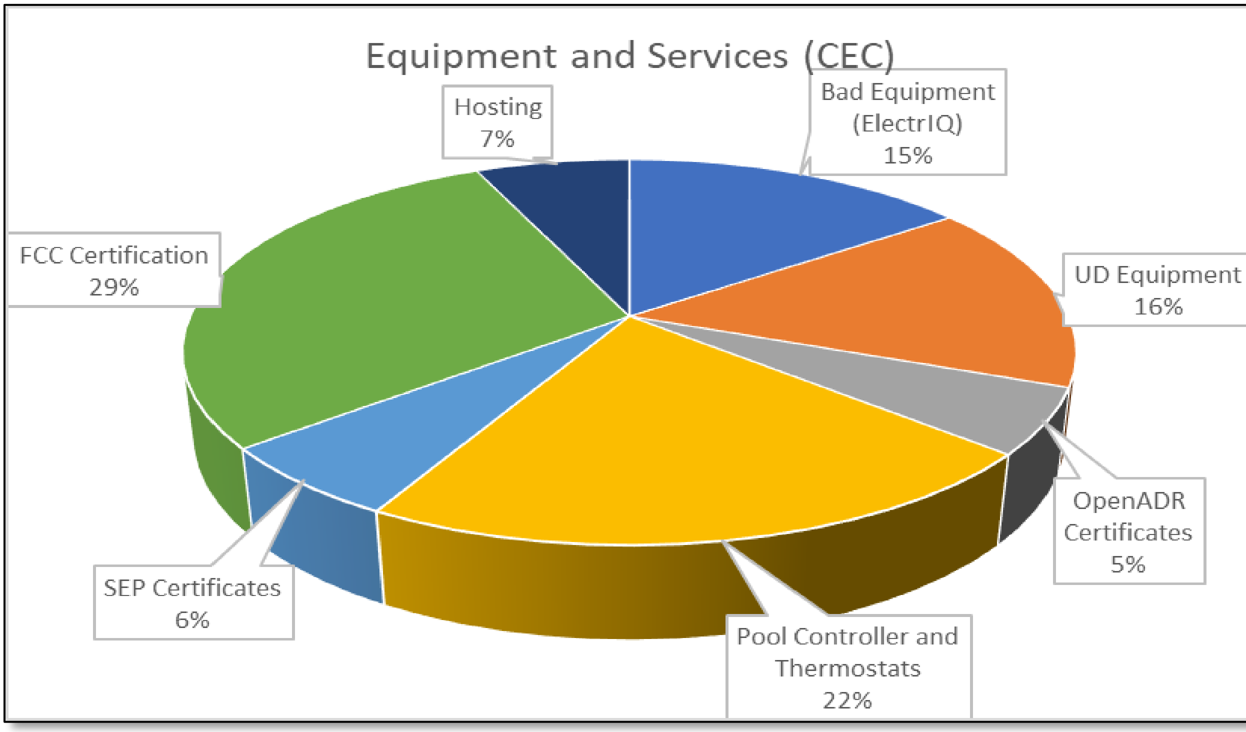
Table 2 and Figure 34 illustrate the reductions in the ISY-related cost at various installation scales. Pool controller and thermostat costs are not included, per the previous paragraph.

Table 2: Customer-Related Universal Devices Costs for RATES

	CEC	1,000	10,000	100,000	1,000,000
Bad equipment (ElectriQ)	$18,000	$0	$0	$0	$0
UD Equipment	$19,000	$190,000	$1,750,000	$15,000,000	$100,000,000
Open ADR Certificates	$6,600	$6,600	$11,000	$25,000	$50,000
Pool Controller and Thermostats	$26,000	$0	$0	$0	$0
SEP Certificates	$7,400	$35,000	$200,000	$1,800,000	$15,000,000
FCC Certification	$35000	$0	$0	$0	$0
Hosting	$8,000	$0	$0	$0	$0
Unused Equipment	($6,500)	$0	$0	$0	$0
Total	$113,500	$231,600	$1,961,000	$16,825,000	$115,050,000
Cost per Participant	$986.96	$231.60	$196.10	$168.25	$115.05
Annual Recurring Fees - Hosting	$0	$20,000	$50,000	$100,000	$200,000
Cost per Participant per year	$0	$20	$5	$1	$0.20

Source: Universal Devices

Figure 34: Shares for Customer-Related Universal Devices Equipment for Current RATES Pilot



Source: Universal Devices

The cost of RATES platforms and communication at 0.10 percent of a customer's bill is likely much less than current billing and settlement systems, although RATES may not avoid some current accounting and settlement costs.

Currently, TeMix pays about $3,000 per month to host its cloud-based infrastructure on Microsoft Azure and Amazon Web Services. This includes production, backup, test, and development systems; and networking costs for registration, database management, Green Button meter data processing, working storage, and archiving. The cost of the RATES production platform is about $750 per month for about 150 participants. The system should be able to handle about 1,500 customers. This is about $0.50 per customer per month and likely will decrease by a factor of 10 as cloud hosting costs in general decline and the RATES systems are operated more efficiently.

Universal Devices' hosting cost for the ISY Portal is about $700 per month.

Complex ISO-like distribution management software systems to dispatch distributed resources and conventional demand response can be very expensive; such costs are avoided with RATES.

RATES can extract much more flexibility from investment in heat pumps, EVs, and distributed storage over the next 25 years than can centralized dispatch and conventional tariffs.

In summary, the case for much greater benefits from RATES over alternatives seems convincing.

Design of Additional RATES Implementations

The design of additional RATES implementations should:

- Focus on facilities and customers with year-round flexible devices such as electric water heaters, electric heat pump HVAC, dispatchable pool pumps, EVs, and battery storage, communicating appliances, and water pumping, including existing "smart homes" and buildings with advanced energy management systems. More such flexible devices are expected given California electrification policies.
- The ADSI and ALSI must be set up for the distribution operator and the load-serving entity to act as market makers and directly interface to their scheduling coordinator and distribution operational systems.
- Implement an opt-in RATES subscription transactive tariff.
- Simplify recruitment, registration, and commissioning using the existing LSE customer account, such as for SCE. On the SCE web site, the customer selects the RATES tariff from among other alternatives, and is automatically registered with RATES and the Green Button metering system. Tenders to the customer facility would begin automatically, and the RATES billing with ex-post 15-minute transactions will begin.
- The customer is provided with a convenient or automated interface to register communicating and controllable devices and provide customer preference information. AI tools would assist the customer in the configuration of devices for RATES.
- At the customer's option, a controller such as the ISY with or without the HAN interface would be delivered to the customer facility and automatically configured with RATES, the HAN if used, and the devices.

This pilot illustrated that installation costs in the customer facility can be the dominant cost of RATES, and that better integration with the existing load-serving entity and distribution operator system is necessary for the proper functioning of RATES.

Potential Future Projects

Below are a set of projects that could be sponsored by EPIC or other parties to advance RATES:

- Research to improve optimization and machine-learning models for HVAC, EVs, dryers, washers, dishwashers, pool pumps, commercial refrigeration, agricultural pumping, standalone storage, integrated solar and storage, and other devices for 24/7 transactive energy price responsiveness. Such research can be used by vendors and others to support the flexible operation of the grid.
- Education and training in RATES for load-serving entity and distribution operator employees including operators, settlement, rate designers, device vendors, regulators, and interested customers.
- Development projects for load-serving entities and distribution operators to implement RATES interfaces, and support in implementing RATES because it will speed its application in furthering California's clean energy goals.

- Development of RATES interface with the California ISO that supports direct creation of RATES tenders at California ISO pricing nodes (pNodes) and direct use of transactions at the pNodes for scheduling and settlement. The capability will improve price communication at the wholesale–retail interface and lower costs through operational efficiency.
- Vendor pilots for RATES automation projects to help vendors implement their interface to RATES.
- Add transactive energy protocol capability to OpenADR.
- Encourage vendors, IOUs, CCAs, municipals, and the California ISO to interface with RATES.
- Prime-the-pump incentives for RATES participation by retail customers.
- Customer incentives to buy flexible devices that work with RATES.
- A very large pilot (over 10,000) to commercialize RATES and behind-the-meter components; and specifically, Energy Expert and automation.
- Use Amazon as the venue for the sales.
- Support all off-the-shelf devices OR have the means for supporting them through a developer marketplace.

CHAPTER 6: Conclusions/Recommendations

This research has achieved its overall goal, as stated:

> *Develop and pilot-test* (proof-of-concept) *a complete, low cost, and standards-based Retail Automated Transactive Energy System (RATES) that maximizes the potential of large numbers of residential and small commercial customers to self-manage their electricity use to save money as California achieves its 2045 100 percent clean energy and electrification goals.*

Key Lessons Learned

As described in this report, RATES performs as designed. However, there are three major categories of lessons learned concerning the application of RATES:

- Requirement for more robust data interfaces.

  The meter data for each facility (home or business) should be reliable and timely. Recently, SCE has announced it will no longer support HAN connections to the meter effective January 1, 2020. Going forward, RATES will use the 15-minute Green Button meter data, with little loss in capability and a lower cost for customer installation and equipment.

  The RATES interface to the California ISO is reasonably reliable but can be improved by working with the California ISO, distribution operators, and load-serving entities to integrate the interface with their scheduling coordinator operations.

  Devices with Z-Wave, Wi-Fi, or other connectivity can be controlled and metered on five-minute intervals. However, the on-premise network and connectivity must be reliable and maintained. There were communications challenges within some homes that required extra effort. Cellular and radio side band communication may help.

  Access to real-time and forecast data on circuit load and SCE net load is needed from the distribution operator and load-serving entity. More effort is required to access these load data automatically.

- Requirement to interface with more flexible devices in retail markets.

  Most California homes have electric air conditioning and natural gas heating. In some areas of California, the climate is moderate, and air conditioning and heating loads are highly variable. In other areas, the air conditioning loads are high in summer but low in the winter. This project demonstrated that RATES could shift and shape air conditioning loads, taking account of the thermal storage in the building to the degree that is useful in heating season.

  California plans to electrify residential heating. In this case, heating and cooling will be electric, such as from heat pumps, and can provide more year-round flexibility. This project demonstrated the flexible operation of heat pumps using RATES.

Residential battery storage, electric vehicle charging, variable speed pool pumps, and electric water heating are other sources of flexibility that are now beginning to be used. These technologies can provide 24/7 flexibility year-round.

- Requirement for widespread use of the subscription transactive tariff and transactive platform.
- The subscription transactive tariff and the transactive platform are necessary to provide the correct incentives for customers and technology vendors to participate in RATES.
- A subscription transactive tariff and transactive platform can now be implemented relatively easily: much more easily than new time-of-use tariffs with fixed charges and associated demand response programs and baselines.

Specifically, as addressed in this research, RATES as a demand-side solution is more effective and more cost-effective in comparison to supply-side solutions such as conventional tariffs and demand response programs for storage, EV charging, and HVAC management.

Recommendations

As outlined in this report, the RATES team recommends the following step-by-step installation of RATES in California and support of the further development of RATES and its wide adoption.

- STEP 1: Extend and apply the current RATES pilot for additional research results at reasonable costs. Recommended tasks include
  - Integrate the three SolarEdge inverters and storage into RATES for storage management.
  - Update the current experimental tariff parameters from the 2015 data inputs to 2019 data inputs.
  - Reengage with a subset of RATES pilot customers and develop more research results on their operations and savings with the updated experimental tariff across a year for any updated devices (such as EVs) that the participants may have purchased.
  - Support the OpenADR Alliance in its planned efforts to integrate transactive energy protocols into the OpenQDR 2.0 standards.
- STEP 2: CPUC initiates workshops and rulemaking to implement opt-in subscription transactive tariffs for IOUs.

  Then CPUC and the IOUs use a subscription transactive tariff for opt-in use by residential, commercial, industrial, and agricultural customers with PV, battery storage, electric vehicles, electric heat pumps, and electric water heaters.

  CCAs and municipal utilities can also use the tariff.

  This step 2 should be coordinated with the state’s electrification policies and incentives.

  A decision to implement the tariff on an opt-in basis will save costs over the status quo. The benefits of RATES can only be discovered with actual buy and sell tenders and transactions that are billed. Vendors, customers, and utilities all require the actual billings to use RATES properly.

- STEP 3: The CPUC and the CEC should establish a policy for hosting the RATES transactive energy platform. The platform can be hosted for the IOUs and CCAs as
    - Hosted by a not-for-profit public benefit corporation, or
    - Hosted by distribution operators, load-serving entities, and private companies.

  Selecting option 1 will preclude a competitive interest in option 2.

  Finally, update the RATES interfaces to the California ISO, distribution operator, and load-serving entities.
- STEP 4: Installation of RATES for customers with storage, electric vehicles, and other flexible devices. Tailoring RATES to each customer's situation can reduce installation costs where the benefits of full RATES use are not yet evident.
- STEP 5: After a few more years of experience with step 4, make the tariff opt-out for most customers.
- STEP 6: Enhance the RATES interface to the California ISO to frequently create wholesale tenders and accept aggregated transactions at the substation pNodes.

GLOSSARY AND ACRONYMS

Term/Acronym	Definition
CISR	Customer Information Service Request
HAN	Home Area Network
EPIC (Electric Program Investment Charge)	The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
ISY	The Universal Devices automation controller.
Smart Grid	The smart grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
Load-Serving Entity (LSE)	Sells and buys kWh to and from retail customers
Distribution Operator	Provides transport services on the distribution grid circuits.
Energy	kWh or average kW delivered over a defined interval of time.
RATES	Retail Automated Transactive Energy System
Reactive Energy	kVARS
Tariff	An enabling agreement between two parties for electricity transactions

TRANSACTIVE ENERGY GLOSSARY

(terms that have a specific meaning within transactive energy as applied by RATES)

Term	Definition
Transactive Energy	Binding tenders and transactions for energy enabled within an agreement between two parties.
Party	An entity that may buy or sell products and control facilities and devices to consume, produce, store or transport products.
Facility	A residence, business, generator, storage battery, distribution circuit or transmission network line, for example.
Meter	Measures delivery of electric energy, typically for a facility.
Commodity	Typically, electric energy, but could be natural gas, oil, etc.
ProductType	Typically, energy or energy transport. Also, may include reactive energy.
Agreement	Enabling agreement that specifies that two parties can transact a product at a defined interface.
Market	A set of agreements or a set of markets with some common attributes.
Duration	A span of time such as a year, month, day, hour, 15 minutes, five minutes or four seconds, used to define the start and duration of intervals for transactions.
Duration Set	A nested set of durations.
Account	For a party, multiple accounts may be used for transactions by the party.
Settlement Type	Indicates a physical transaction intended for delivery or a financial transaction intended for settlement for differences with respect to a market index.
Interface	Where products are transacted, defined by injection node and takeout node: these two nodes are the same for an energy product and different for a transport product.
Injection Node	A location on the electric grid where energy is typically injected.
Takeout Node	A location on the electric grid where power is typically taken out.
Tender	An offer (typically binding) to buy or sell a product at an interface for an interval.
Tender Type	Indicates whether a tender is binding or nonbinding.
Transaction	A binding commitment on both parties to buy or sell a product at an interface for an interval.

Term	Definition
Position	The total quantity and extended price (cost or revenue) of a product transaction on a specific interval and interface.
Price	Currency units per energy unit, typically $/kWh or $/MWh.
Quantity	Rate of delivery of energy over an interval, typically kW or MW (multiplying by the duration in hours gives kWh or MWh).
Delivery	The quantity of energy delivered over an interval as measured by a meter.
Side	Buy or sell from the perspective of the party that initiated a tender.

REFERENCES

Barrager, Stephen, and Edwar Cazalet. 2016. "51st State Roadmap, Sustainable Business, and Regulatory Model: Transactive Energy." *sepapower.com.*

https://sepa.force.com/CPBase__item?id=a12o000000TOYIaAAP.

Barrager, Stephen, and Edward Cazalet. 2014. *Transactive Energy: A Sustainable Business and Regulatory Model for Electricity.* Baker Street Publishing.

https://itunes.apple.com/us/book/transactive-energy/id894811747.

Cazalet, Edward G. 2011. "Automated Transactive Energy (TeMix)."

http://www.cazalet.com/images/E-commerce_for_Electricity.pdf.

Cazalet, Edward G., and Ram Sastry. Shellury. 2012. "Transactive Device Architecture and Opportunities."

http://www.temix.net/images/GI12-Paper-12032012-Final_Cazalet_Sastry.pdf.

OASIS. 2014. "Energy Interoperation Version 1.0."

https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=energyinterop.

OASIS. 2012. "Energy Market Information Exchange (EMIX) Version 1.0." http://docs.oasis-open.org/emix/emix/v1.0/emix-v1.0.html.

APPENDIX A: RATES Stakeholder and Pilot Participant Report

Stakeholder and Pilot Participants Report Purpose

The purpose of this appendix is to develop and provide a Stakeholder and Pilot Participant Report:

- Describes how Universal Devices Inc (UDI) will engage relevant stakeholders, specifically how the UDI will ensure that a California IOU and California ISO fulfill their participation commitments in their letters of support for the grant application.
- Explains how UDI will work with Southern CA EDISON (SCE), to recruit pilot participants.
- Describes how UDI will identify the list of potential pilot participants and includes a list of potential participants for executing Task 4:
- Consistent with "Exhibit E Electric Program Investment Charge Special Terms and Conditions,"
- Participants should be made up of approximately:
- Eighty percent of residential customers and 20 percent small/medium commercial customers.
- Five percent of customers with solar and storage.

Southern California Edison

Mark Martinez, the Emerging Markets and Technology Manager at Southern CA Edison (SCE), is the SCE executive lead for the RATES project. Mr. Martinez identified several key team members within SCE who provide technical support. Additional resources are brought in on occasion to support a specific topic.

The key ongoing SCE subject matter expert team members include:

- Mauro Dresti
- Robert Thomas
- Reuben Behlihomji
- Cyrus Sorooshian

Universal Devices set up bi-weekly calls in which project representatives from SCE, TeMix and Universal Devices review the project status, requirements and related issues. Additional calls are scheduled based on project needs. Many technical review and analysis meetings have been conducted to analyze the RATES system requirements. Based on the requirements, the above team identified and set up a meeting with the appropriate SCE resource.

California Independent System Operator

Mr. Tom Doughty, VP of Customer and State Affairs, was the primary executive point of contact at the California ISO for the RATES project. As described in the California ISO support letter signed by Mr. Doughty, RATES will directly communicate with the ISO portal to access hourly, 15-minute, and 5-minute pNode LMPs at an SCE substation. TeMix has used the California ISO's API to automatically download these LMPs as they are published by the ISO Portal.

Once the California ISO LMPs are fully integrated into the RATES, the project team will demonstrate how RATES can provide price responsiveness and visibility to the ISO to enable better use of renewables and other benefits. TeMix also plans to suggest adding the capability to the interface between the California ISO and RATES.

Volunteer Geographical Area and Circuit Selection

After holding multiple RATES system analysis meetings, the TeMix, SCE, and Universal Devices team have identified the SCE distribution circuits and communities connected to SCE's Moorpark substation as the focus for this project. A map of the Moorpark substation circuit is included in Appendix D. The communities in this area are said to have a strong interest in clean energy and energy management, including customers with solar and electric vehicles.

The Moorpark communities are impacted by the Aliso Canyon gas storage crisis that RATES could help address type of crisis.

An additional factor in the circuit selection was based on SCE anonymous data, which was analyzed by Dr. Ed Cazalet and his team within TeMix. The sample data SCE has provided includes anonymous customer 3-year load data for both solar and no solar customers. SCE has also provided sample circuit data that has enabled the team to test alternative ways to create energy and distribution subscriptions for volunteer customers.

To reach potential participants within the selected circuit, Universal Devices has reached out to the local senator, Senator Stern, and his office. Senator Sterns staff provided continuous support in identifying ways to recruit potential participants by reaching each mayor within the cities identified as part of the Moorpark substation circuit. A representative from Universal Devices was encouraged to attend City Council meetings and offer local communities the opportunity to become participants for this study. Universal Devices will continue attending local community-based programs and events in the potential participant recruitment process.

Potential Participants Commitment Process Description

Consistent with "Exhibit E Electric Program Investment Charge Special Terms and Conditions", Universal Devices will interview potential participants in the selected area. Each participant will be given both verbal and written explanation detailing what they will receive by participating in this pilot and what will be required of them. The written documentation is included in Appendix A, under the heading Initial Project Documentation for Pilot Participants. The documentation includes the name of this grant and a link to the CA Energy Commission's web site and a high-level description of the grant. The documentation also includes the benefits of the Universal Devices project, the specific benefits to each participant, and the requirements from each volunteer.

Universal Devices representative will contact each potential participant. A special support team has been identified to support pilot participants. Each participant will have to complete the standard form 14-796, also known as the CISR form, used by the three large IOU's in California. The CISR form is a standard legal document used by Southern CA EDISON (as well as PG&E and SDG&E.) In this document, a customer can specify what type of permission or access he will give a third party. It also identifies the length of time this access will be in effect. Universal Devices is identified as the third party on the CISR form sent to participants. This form is necessary because Universal Devices would like to have up to three years of historical data for each volunteer. This data will be used in the RATES system both in setup and optimization algorithms.

As Universal Devices processes the CISR form, it will comply with the Information Practices Act as codified in California Civil Code sections 1798 to the best of its abilities. The information provided by the pilot participants will be maintained securely and will not be distributed to anyone who is not directly involved in this grant. Only Universal Devices and TeMix team members who have been approved as part of the grant's working team will have access to pilot participant's personal data.

Initial Project Documentation for Pilot Participants

GFO-15-311 ADVANCING SOLUTIONS THAT ALLOW CUSTOMERS TO MANAGE THEIR ENERGY DEMAND

- Mission Statement:
  - Enable homeowners to control their own energy use!
  - Energy at a reduced cost
  - Greater environmental benefits
  - Edison customers that would like to enjoy the benefits of this grant, please Contact: Orly Hasidim orly@universal-devices.com 818.489.7672
  - Only Southern CA Edison Customers can participate
  - Volunteer Benefits:
  - You set your desired comfort level versus cost.
  - Help in the effort to reduces carbon-based fuels use
  - Enables more solar and storage in your community- reduces natural gas usage and air emissions.
  - You can help prove out concepts for Transactive Energy that can enable a 100 percent renewable future for California, and stable electricity costs.
- Hardware
  - Smart Home Controller: ISY994 ZS Series: https://www.universal-devices.com/utility/isy-994i-zs-series/
  - Thermostat (s): https://www.amazon.com/RCS-Z-Wave-Communicating-Thermostat-001-01773/dp/B007C8UJLI/ref=sr_1_1?ie=UTF8&qid=1483553343&sr=8-1&keywords=tz45
  - Pool Controller: http://www.rcstechnology.com/pages/products/power-monitoring-cc.html
  - Multi-sensor(s): https://www.amazon.com/Aeon-Labs-Aeotec-Z-Wave-Multi-Sensor/dp/B00S68NUSW/ref=sr_1_3?ie=UTF8&qid=1483553497&sr=8-3&keywords=z-wave+multi+sensor
  - Software

    - ISY Portal: http://wiki.universal-devices.com/index.php?title=Main_Page#ISY_Portal.2FAmazon_Echo.2FIFTTT
    - Geo fencing app http://wiki.universal-devices.com/index.php?title=ISY_Portal_Node_Server_Occupancy_percent26_Locative_app_Instructions
- Installation Services
    - Tech support
    - https://www.universal-devices.com/udi-support/
    - http://www.universal-devices.com/contact-support/
    - Integration with Smart Meter
    - http://wiki.universal-devices.com/index.php?title=Main_Page#Smart_Grid-ISY994_ZS_Series
- Solar panel integration and Storage (in some cases)
- Automation and energy management system that optimizes energy usage
- Provide feedback and energy usage/cost information
- Allow easy command/control of devices and preferences even remotely
    - Supports voice commands (we do not pay for Alexa or Google Home) and may support voice responses (Google Home)

Civil Code 1798

PART 4. OBLIGATIONS ARISING FROM PARTICULAR TRANSACTIONS [1738 3273]

ARTICLE 1. General Provisions and Legislative Findings [1798 1798.1] (Article 1 added by Stats. 1977, Ch. 709.)

1798.

This chapter shall be known and may be cited as the Information Practices Act of 1977. (Added by Stats. 1977, Ch. 709.)

1798.1.

The Legislature declares that the right to privacy is a personal and fundamental right protected by Section 1 of Article I of the Constitution of California and by the United States Constitution and that all individuals have a right of privacy in information pertaining to them. The Legislature further makes the following findings:

(a) The right to privacy is being threatened by the indiscriminate collection, maintenance, and dissemination of personal information and the lack of effective laws and legal remedies.

(b) The increasing use of computers and other sophisticated information technology has greatly magnified the potential risk to individual privacy that can occur from the maintenance of personal information.

(c) In order to protect the privacy of individuals, it is necessary that the maintenance and dissemination of personal information be subject to strict limits.

Southern CA EDISON CISR Form

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

AUTHORIZATION TO: RECEIVE CUSTOMER INFORMATION OR ACT ON A CUSTOMER'S BEHALF

THIS IS A LEGALLY BINDING CONTRACT – READ IT CAREFULLY

I,

NAME

of__(Customer) have the following mailing address
NAME OF CUSTOMER RECORD

____, and do hereby appoint
MAILING ADDRESS CITY STATE ZIP
of
NAME OF THIRD PARTY MAILING ADDRESS

CITY STATE ZIP

to act as my agent and consultant (Agent) for the listed account(s) and in the categories indicated below: ACCOUNTS INCLUDED IN THIS AUTHORIZATION
1. _ _______
SERVICE ADDRESS SERVICE ACCOUNT NUMBER

2. _ _______
SERVICE ADDRESS SERVICE ACCOUNT NUMBER

3. _ _______
SERVICE ADDRESS SERVICE ACCOUNT NUMBER
(For more than three accounts, please list additional Service Addresses and Service Account Numbers on a separate sheet and attach it to this form)

INFORMATION, ACTS AND FUNCTIONS AUTHORIZED This authorization provides authority to the Agent. The Agent must thereafter provide specific written instructions/requests (e-mail is acceptable) about the particular account(s) before any information is released or action is taken. In certain instances, the requested act or function may result in cost to you, the customer. Requests for information may be limited to the most recent 12 month period.

I (Customer) authorize my Agent to act on my behalf to perform the following specific acts and functions (initial or put an 'x' inside all applicable boxes):

1. Request and receive billing records, billing history and all meter usage data used for bill calculation for all of my account(s), as specified herein, regarding utility services furnished by the Utility.[1]
2. EPA Benchmarking
3. Request and receive copies of correspondence in connection with my account(s) concerning (initial all that apply):
a. Verification of rate, date of rate change, and related information;
b. Contracts and Service Agreements;
c. Previous or proposed issuance of adjustments/credits; or
d. Other previously issued or unresolved/disputed billing adjustments.
4. Request investigation of my utility bill(s)
5. Request special metering, and the right to access interval usage and other metering data on my account(s).
6. Request rate analysis.
7. Request rate changes.
8. Request and receive verification of balances on my account(s) and discontinuance notices.

- The Utility will provide standard customer information without charge up to two times in a 12 month period per service account. After two requests in a year, I understand I may be responsible for charges that may be incurred to process this request.

AUTHORIZATION TO: RECEIVE CUSTOMER INFORMATION OR ACT ON A CUSTOMER'S BEHALF
I (CUSTOMER) AUTHORIZE THE RELEASE OF MY ACCOUNT INFORMATION AND AUTHORIZE MY AGENT TO ACT ON MY BEHALF ON THE FOLLOWING BASIS[2] (initial one box only):

One time authorization only (limited to a one-time request for information and/or the acts and functions Specified above at the time of receipt of this Authorization).
One year authorization Requests for information and/or for the acts and functions specified above will be accepted and processed each time requested within the twelve month period from the date of execution of this Authorization.
Authorization is given for the period commencing with the date of execution until ____(Limited in duration to three years from the date of execution.) Requests for information and/or for the acts and functions specified above will be accepted and processed each time requested within the authorization period specified herein
RELEASE OF ACCOUNT INFORMATION:

The Utility will provide the information requested above, to the extent available, via any one of the following. My (Agent) preferred format is (check all that apply):

Hard copy via US Mail (if applicable): ___________ Facsimile at this telephone number: ___
Electronic format via electronic mail (if applicable) to this e-mailaddress:________

I (Customer),______(print name of authorized signatory), declare under penalty of perjury under the laws of the State of California that I am authorized to execute this document manually or electronically on behalf of the Customer of Record listed at the top of this form and that I have authority to financially bind the Customer of Record. I further certify that my Agent has authority to act on my behalf and request the release of information for the accounts listed on this form and perform the specific acts and functions listed above. I understand the Utility reserves the right to verify any authorization request submitted before releasing information or taking any action on my behalf. I authorize the Utility to release the requested information on my account or facilities to the above Agent who is acting on my behalf regarding the matters listed above. I hereby release, hold harmless, and indemnify the Utility from any liability, claims, demands, causes of action, damages, or expenses resulting from:
1) any release of information to my Agent pursuant to this Authorization; 2) the unauthorized use of this information by my Agent; and 3) from any actions taken by my Agent pursuant to this Authorization, including rate changes. I understand that I may cancel this authorization at any time by submitting a written request. **[This form must be signed by someone who has authority to financially bind the customer (for example, CFO of a company or City Manager of a municipality).]**

____

AUTHORIZED CUSTOMER SIGNATURE TITLE (IF APPLICABLE) TELEPHONE NUMBER

Executed this_____day of___________ at ______
MONTH YEAR CITY AND STATE WHERE EXECUTED

I (Agent), hereby release, hold harmless, and indemnify the Utility from any liability, claims, demand, causes of action, damages, or expenses resulting from the use of customer information obtained pursuant to this authorization and from the taking of any action pursuant to this authorization, including rate changes. I also hereby indicate my consent to execute and submit this signature electronically.

____

AGENT SIGNATURE TELEPHONE NUMBER

COMPANY

Executed this_____day of ___ ______
MONTH YEAR

____

____

If no time period is specified, authorization will be limited to a one-time authorization.

Volunteer Assessment and Engagement Doc

CEC Grant GFO-15-311

Universal Devices Volunteer Agreement and Assessment Form

Universal Devices' Obligations

Privacy

Important to note that Universal Devices Inc. will comply with the Information Practices Act ("IPA") as codified in California Civil Code sections 1798 et seq. All information provided to Universal Devices by the volunteers in this project is protected and will only be used for the purposes of this grant. The volunteer's personal information such as name, address, telephone, email and any additional information requested by the volunteer, excluding the meter readings, shall not be used in any public document, shall not be shared with anyone outside the immediate team, shall not be used in any marketing campaigns of any sorts, and shall not even be included in the report to the CA Energy Commission. Volunteer's private information will only be used to communicate with Southern CA EDISON and the automation installer. Universal Devices will protect volunteer's private information and maintain it in the most secure manner.

Financial

Hardware, Software, Installation, and support services costs will be covered by the funds provided by the California Energy Commission dedicated to this grant.

Volunteer Obligations

Volunteers will provide written permission as per Southern CA Edison's requirements to allow Universal Devices to receive their meter information.

The meter reading information will be limited in time to the following:

- A minimum of a 12 months and up 36 months prior to the automation system installation
- 12-18 months following automation system installation

Volunteers will provide truthful information (to the best of their knowledge) to the Universal Devices and the installer and also provide installer access to for the system installation.

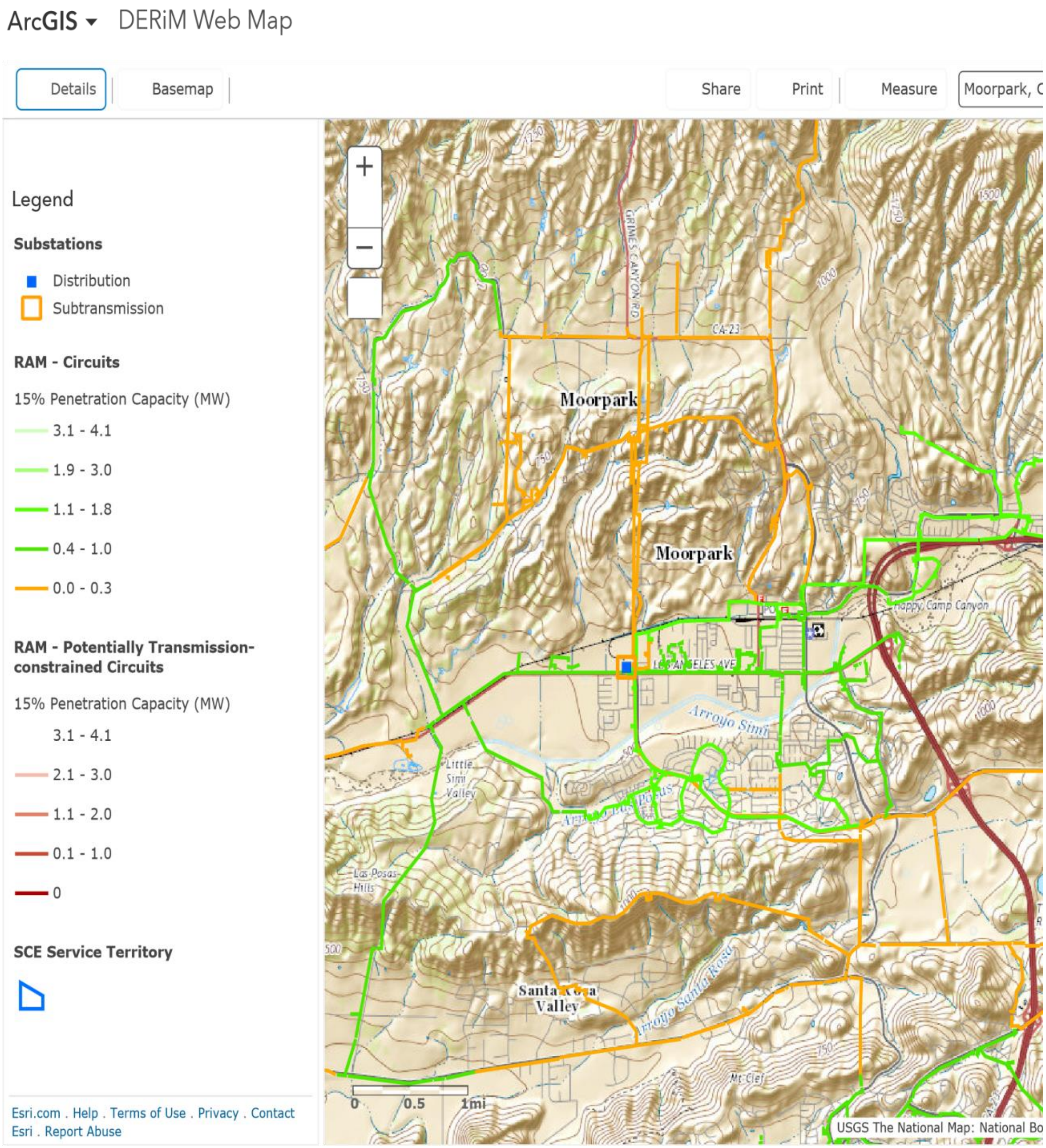
No financial obligation is required from volunteers at any point in this project.

Installation Site Assessment Information

- Name:
- Address:
- Email:
- Phone:
- Is this a Residence or a Business venue?
- Do you have an EDISON smart meter, also known as NEM 2.0 meter?
- Approximate size of your residence/business
- Do you currently have automation devices installed in the residence/business. Example: Phillips Hue, Nest Thermostat, etc.
- Do you have a pool? Can it be controlled from an app on your phone?
- Do you have PV/Solar System?
- Do you have an Electric Vehicle?
- Make
- Model
- Do you know if your water heater is electric?
- How many thermostats do you have in your residence/business? Are they battery operated?
- Do you have internet in this location?
- Do you have any open ports on your routers in this location?
- Preferable time for automation system installation:

Moorpark Substation Circuit Map

The Circuit map below is based on ArcGIS on-line web map.



Phase 2 Participation Agreement

GRANT FUNDING OPPORTUNITY GFO-15-311

Advancing Solutions That Allow Customers To Manage Their Energy Demand

We appreciate your participation in our study. As a reminder, the purpose of this pilot is to develop and demonstrate systems that will help you manage your electricity use and bills to support more renewable solar electricity on the California grid, reduce greenhouse gases and air pollution and potentially save you money. You have already been provided certain smart home technology and you have granted Universal Devices access to your electricity meter data via the Southern California Edson (SCE) web site. Thank you very much for your participation in the study to date and for your help in meeting California's climate goals!

Phase 2 the RATES Tariff

The next Phase 2 of this pilot is designed to determine how smart home technology can provide additional cost-savings management support to help you manage your energy demand.

For pilot participants who voluntarily decide to participate in this next Phase 2 of the study, we will supplement your current SCE tariff (rate plan) with a RATES tariff with electricity prices that will be more variable but provide you with savings if you use less when RATES prices are high and more when prices are low. You will have voice control via Alexa and via a website over how much RATES automatically adjusts your thermostat, for example, to maintain your comfort and achieve savings. Other opportunities will be explored for other appliances.

As illustrated in the above chart, each month, you will continue to receive your regular SCE bill and pay it in accordance with the SCE requirements. For the Phase 2, you will also receive a separate RATES monthly statement that you will NOT pay. The purpose of the RATES statement is to identify how much money you would have saved under the experimental RATES tariff.

The RATES tariff is designed to save money, but the SCE bill may not reflect the savings.

To make sure you are not paying more than you should, Universal Devices and TeMix, using the grant funds from the California Energy Commission, will provide you with a rebate if the RATES statement indicates that you would have saved money as a participant in the RATES pilot.

This being a pilot the RATES team retains the right to suspend participation in any case in which a problem is identified and may reinstate the participation once the problem is resolved.

You are always welcome to provide any feedback you have at via email at https://rates.energy/ or at (818) 631-0333 option 3.

You will have access to detailed reports and summaries of all RATES transactions and rebates, so you can see how much you may be saving and understand how you can save more. Southern California Edison and the California Public Utilities Commission via Advice Letter have permitted Universal Devices Inc. and TeMix Inc. to make this offer to you.

Yes, I would like to participate in the RATES tariff!

Accepted by Participant

Signature:

Name:

Address:

Date:

Thank you. Together we will create a better tomorrow!

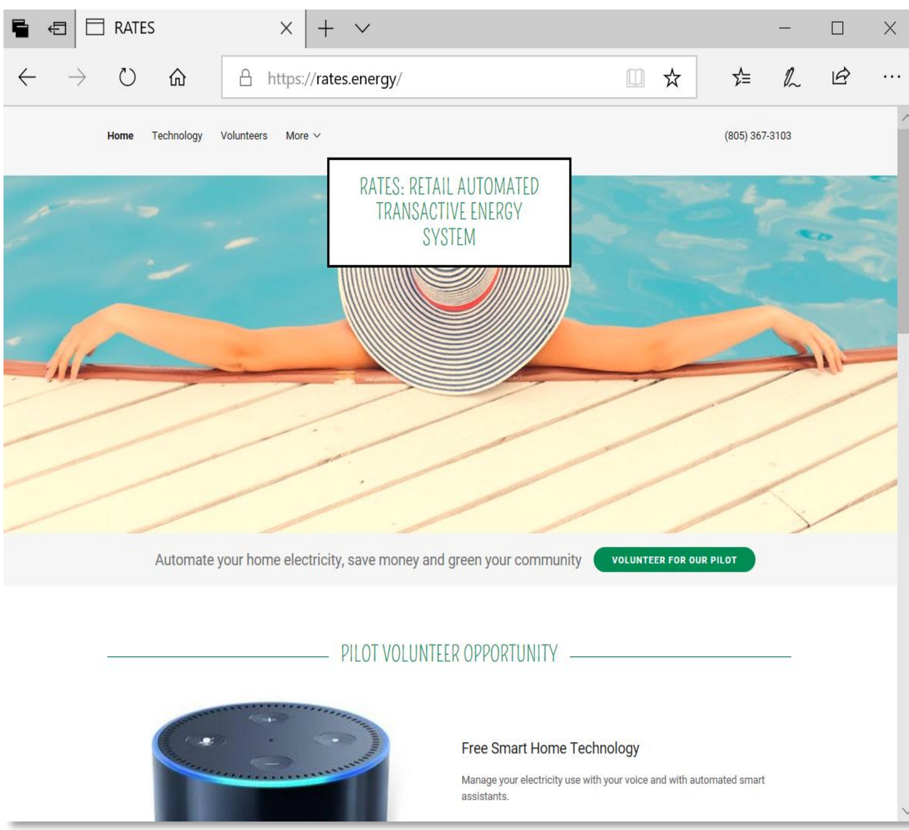
APPENDIX B:
Pilot Participation Verification and Deployment Memo

Pilot Participant Interaction and Feedback Summary

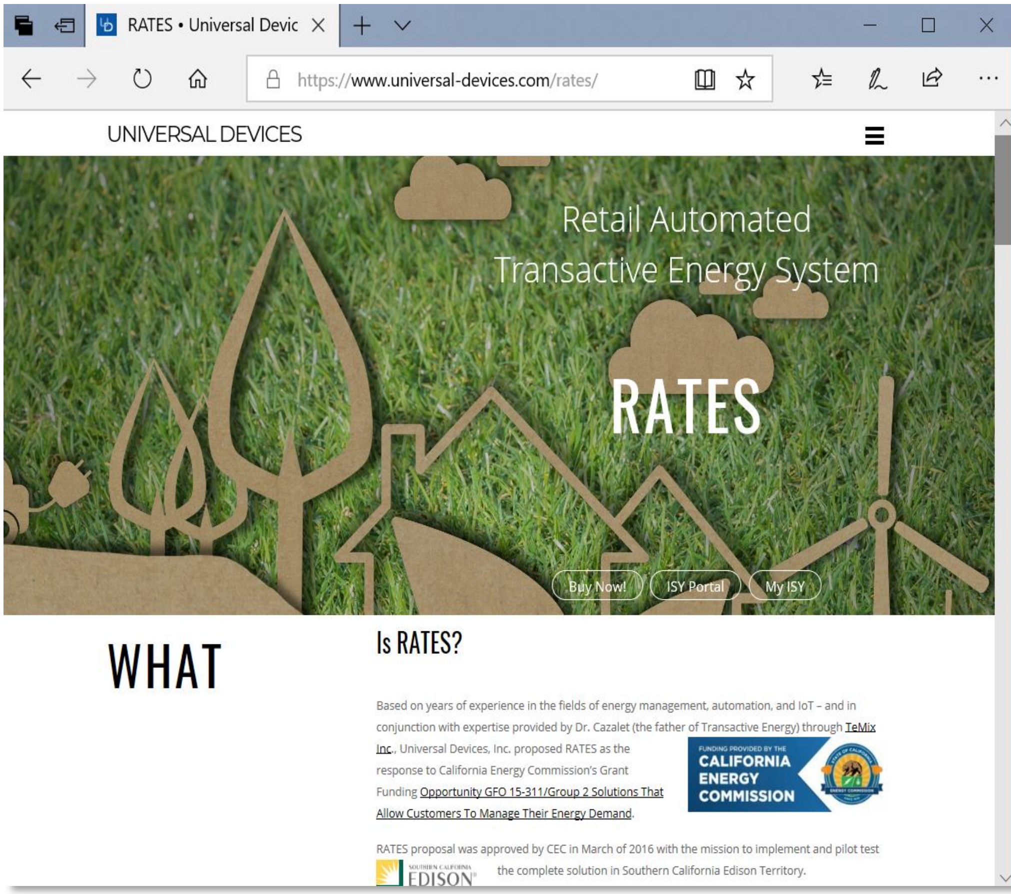
Universal Devices lead most of the interaction with the pilot participants. SCE contributed by adding Chris Mellen and Christie Kjellman to help manage pilot participant outreach and interactions. At the onset of the pilot, 90 percent of the people who signed up expressed that they are signing up because they would like to help the environment and because they would like to support the exploration of a new system to purchase energy. Participants expressed frustration having no data about the cost of their energy consumption until the bill arrives at the end of the cycle. SCE's help desk was briefed about the project and was instructed to contact Mark Martinez if pilot participants had questions about the pilot. Four people called the help desk. All calls were during the pilot participant recruitment phase of the pilot. Two websites were created to provide participants with additional information about the pilot: www.RATES.energy and https://www.universal-devices.com/rates/

The web sites were created to provide detailed information for the pilot participants. The web site included information about the grant, such as a link to the CA Energy Commission's grant solicitation, a link to the proposal to the CEC for the project, explanations of benefit, RATES Architecture, and project milestones.

Below is a screenshot of www.rates.energy



Below is a screenshot of https://www.universal-devices.com/rates/



Participants were encouraged throughout the project to provide feedback to the RATES team via email or phone. Orly was available via email and phone to support their questions and concerns. The feedback after the installation included both positive and negative elements. The positive comments were about the professionalism of the installer and the appreciation for the equipment received. The negative was mostly about the meter dysfunction and having to be on a new billing cycle due to the meter replacement.

Based on input from the participants toward the end of the pilot, the following conclusion were reached:

5 percent of the Participants are:

- Enthusiasts
- Always responsive and active
- Most have PVs or an EV
- Extended their system above and beyond the pilot

85 percent of the Pilot Participants are:

- Receptive
- Rather responsive but prefer not to be contacted
- If the interaction is not simple, you lose them

10 percent of Pilot Participants are:

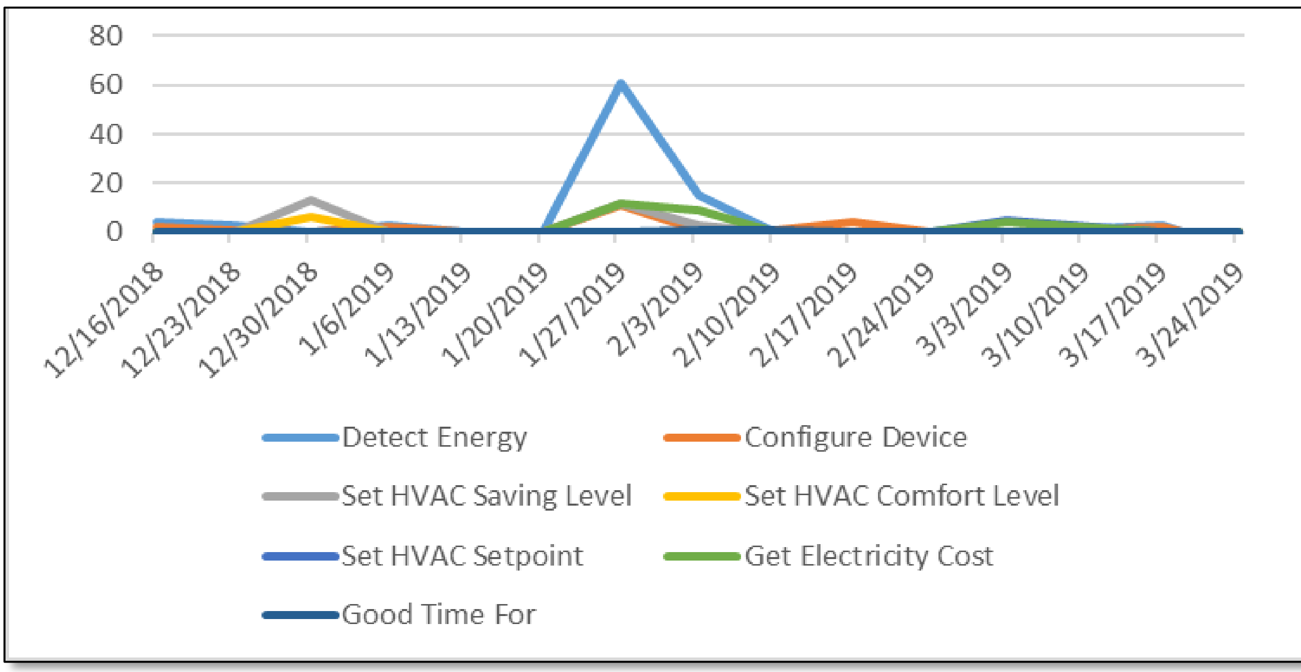
- There only for the free stuff
- Do not bother me attitude

Pilot participants interacted with the RATE system through the Alexa skill- Energy Expert. Participants liked using the Smart Home skill mostly to control the thermostat and, on rare occasions, the pool pump. The enthusiasts added additional devices such as lights and various sensors. They used the Energy Expert skill to interact with all the devices they added to the automation system.

The following conclusions are based on the analysis of the pilot participants interactions:

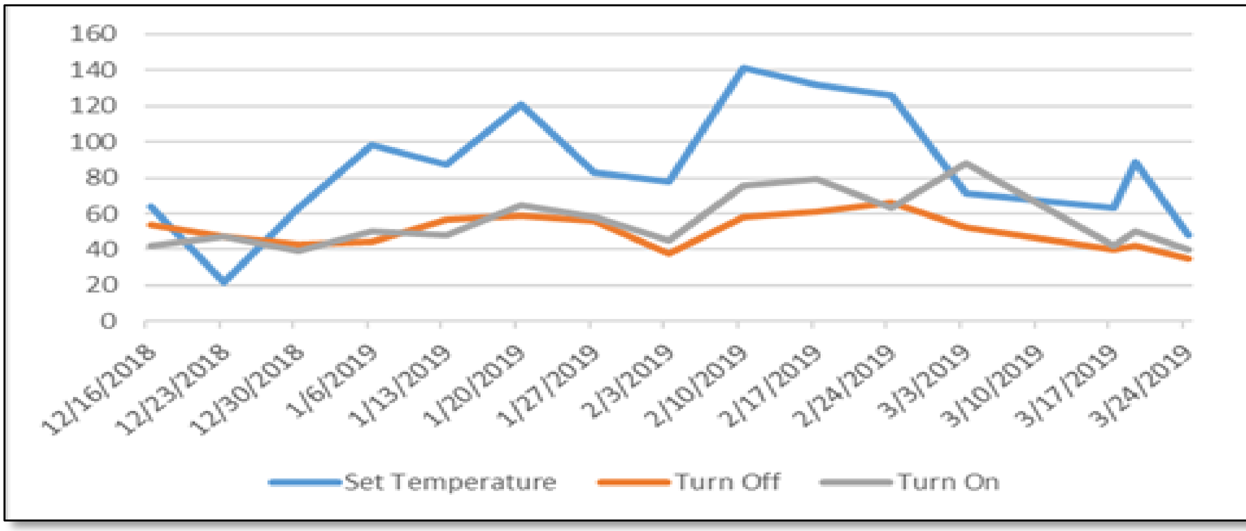
- The Enthusiasts use Energy Expert Skill
- Energy Expert usage and spikes are mostly due to email campaigns
- Smart Home skill was used by many more than the Energy Expert and had very little to do with any email campaigns

Figure B-1: Energy Expert Skill Usage



Source: Universal Devices

Figure B-2: Smart Home Skill Usage



Source : Universal Devices

Pilot Participant Listing

Two lists are in this Appendix. The first is the listing from the RATES help desk. The second is the listing of from within the RATES system.

RATES Help Desk Pilot Participant List

The following is a list of the participants in the Help Desk system designed to maintain the pilot participants. All personal information has been removed. All the pilot participants that were interested in the pilot and that provided information during the recruitment process are included in the list below. Not all the people listed completed all the paperwork required or were qualified to be included in the pilot. Customers did not qualify if they did not live in the same location for three years before the installation date.

Table B-1: Participants in Help Desk System

Modified	Full Name	Home Phone	Email Address	Status	Address	City
12/19/2018 11:30				Rejected by RATES	Jenny Drive	Newbury Park
11/8/2018 14:46				Installation Complete	Shadow Wood Place Moorpark, Ca 93021	Moorpark
9/11/2018 15:11				Installation Complete	Eaglewood Avenue	Thousand Oaks
7/19/2018 11:35				Installation Complete	Silkwood Rd	Aliso Viejo
7/19/2018 11:26				Installation Complete	W. Hawthorne St.	Ontario
7/2/2018 9:00				Installation Complete	Birch Street	Santa Ana
7/2/2018 8:31				Rejected by Prospect	Valley High Ave.	Thousand Oaks
7/1/2018 15:26				Installation Complete	Michael Drive	Newbury Park
7/1/2018 15:26				Installation Complete	Sawmill Lane	Lake Forest
7/1/2018 15:17				Installation Complete	Cove St	Costa Mesa
7/1/2018 15:17				Installation Complete	Amaganset Way	Tustin
7/1/2018 15:17				Installation Complete	N. Citrus	Orange
7/1/2018 15:14				Installation Complete	East Quincy Ave	Orange
7/1/2018 15:14				Installation Complete	Lindero Canyon Rd. Suite D3	Westlake Village
7/1/2018 15:10				Installation Complete	Silverado Drive	Thousand Oaks
7/1/2018 15:10				Installation Complete	La Cadena Dr	Laguna Hills
7/1/2018 15:07				Rejected by Prospect	Cedarhaven Dr	Agoura Hills
7/1/2018 15:06				Installation Complete	Nutwood Ave	Fullerton
5/27/2018 19:57				Installation Complete	Orchardview Ct	Westlake Village
5/18/2018 15:16				Installation Complete	Chestnut Ridge St	Moorpark
5/7/2018 9:13				Installation Complete	Vista Entrada	Newport Beach
5/7/2018 9:11				Installation Complete	Clear Haven Dr	Oakpark
5/2/2018 16:43				Installation Complete	Rosario Dr	Thousand Oaks

Modified	Full Name	Home Phone	Email Address	Status	Address	City
4/9/2018 14:32				Installation Complete	Montrose Dr	Thousand Oaks
4/9/2018 14:30				Installation Complete	Hawksway Ct	Westlake Village
4/9/2018 14:30				Installation Complete	Beech Rd	Newbury Park
4/9/2018 14:29				Installation Complete	Woodbridge Lane	Simi Valley
4/9/2018 14:29				Installation Complete	W Sierra Dr	Thousand Oaks
4/1/2018 13:44				Installation Complete	Warwick Ave	Thousand Oaks
4/1/2018 13:44				Installation Complete	Alscot Ave	Simi Valley
4/1/2018 13:43				Installation Complete	Regina Avenue	Thousand Oaks
4/1/2018 13:43				Installation Complete	Arroyo View St	Newbury Park
3/30/2018 22:05				Installation Complete	Varsity St	Moorpark
3/30/2018 22:05				Installation Complete	Kazuko Ct	Moorpark
3/30/2018 22:05				Installation Complete	S Blue Ridge Ct	Thousand Oaks
3/30/2018 22:05				Installation Complete	Capella Way	Thousand Oaks
3/28/2018 20:13				Installation Complete	Ambridge Dr	Calabasas
3/28/2018 20:13				Installation Complete	Drayton Ave	Thousand Oaks
3/8/2018 16:16				Installation Complete	Cynthia St	Simi Valley
3/8/2018 16:15				Installation Complete	Cornett Ave	Moorpark
3/8/2018 16:15				Installation Complete	Brigantine Circle	Westlake Village
3/8/2018 16:15				Installation Complete	Birchwood Ave	Oak Park
2/27/2018 14:40				Rejected by RATES	Chaucer Pl	Thousand Oaks
2/23/2018 8:02				Rejected by Prospect	Valley Spring Dr	Westlake Village
2/22/2018 16:38				Installation Complete	Willow Hill Dr	Moorpark
2/22/2018 16:37				Installation Complete	Saddlecrest Lane	Westlake Village

Modified	Full Name	Home Phone	Email Address	Status	Address	City
2/15/2018 17:35				Installation Complete	Gum Circle	Simi Valley
2/13/2018 13:24				Waiting for Participant Application		Newbury Park
2/12/2018 16:27				Installation Complete	Silver Shadow Dr	Newbury Park
2/12/2018 16:27				Installation Complete	Kathleen Dr	Newbury Park
2/8/2018 10:12				Installation Complete	Azalea St	Thousand Oaks
2/8/2018 10:12				Installation Complete	McCrea Rd	Thousand Oaks
2/8/2018 9:06				Installation Complete	Seabridge Drive	Fremont
2/1/2018 9:01				Rejected by Prospect	Willow Forest Dr	Moorpark
1/31/2018 15:13				Waiting for Participant Application	Softwind Way	Agoura Hills
1/19/2018 16:41				Installation Complete	Canyon Crest Dr	Simi Valley
1/19/2018 16:37				Installation Complete	Foxfield Dr	Westlake Village
1/19/2018 12:32				Installation Complete	Woodstone Ct	Thousand Oaks
1/19/2018 9:58				Installation Complete	Casino Dr	Thousand Oaks
1/19/2018 9:58				Installation Complete	Bluesail Circle	Westlake Village
1/19/2018 9:58				Installation Complete	Hiram Ave	Newbury Park
1/19/2018 9:58				Installation Complete	Corning St	Newbury Park
1/19/2018 9:58				Installation Complete	E. Little Las Flores Rd	Topanga
1/19/2018 9:58				Installation Complete	Fairview Rd	Thousand Oaks
1/19/2018 9:10				Waiting for Participant Application		
1/12/2018 14:09				Installation Complete	Gerald Dr	Newbury Park
1/12/2018 14:07				Installation Complete	Camino Calandria	Thousand Oaks
12/18/2017 10:42				Installation Complete	Diververnon Ave	Simi Valley

Modified	Full Name	Home Phone	Email Address	Status	Address	City
12/15/2017 13:13				Installation Complete	Lake Lindero Dr	Agoura Hills
12/15/2017 12:19				Installation Complete	Seitz Ct	Moorpark
12/15/2017 10:28				Installation Complete	Read Rd	Thousand Oaks
12/12/2017 17:17				Installation Complete	Calle Artigas	Thousand Oaks
11/29/2017 23:54				Installation Complete	Valley Spring Dr	Westlake Village
11/29/2017 21:54				Installation Complete	Orchard View Ct	Westlake Village
11/29/2017 21:54				Installation Complete	Ramona Dr	Newbury Park
11/29/2017 21:54				Installation Complete	Via Don Luis	Newbury Park
11/29/2017 21:54				Installation Complete	Young Ave	Thousand Oaks
11/29/2017 21:54				Installation Complete	Saddlehorn Pl	Newbury Park
11/8/2017 7:39				Installation Complete	Lear Circle	Thousand Oaks
11/6/2017 14:08				Installation Complete	Via Sandra	Newbury Park
11/3/2017 9:55				Installation Complete	Limestone Dr	Thousand Oaks
11/3/2017 9:55				Installation Complete	Seven Oaks Ct	Westlake Village
11/3/2017 9:54				Installation Complete	Globe Ave	Thousand Oaks
11/3/2017 9:54				Installation Complete	WestBluff Pl	Simi Valley
11/3/2017 9:53				Installation Complete	El Verano Dr	Thousand Oaks
10/23/2017 11:42				Installation Complete	Mallory Ct	Moorpark
10/19/2017 10:48				Installation Complete	Watergate Ct	Westlake Village
10/16/2017 18:58				Installation Complete	Sandtrap Dr	Agoura Hills
10/16/2017 15:12				Installation Complete	Owburn Ct Suite #100	Westlake Village

Modified	Full Name	Home Phone	Email Address	Status	Address	City
10/16/2017 14:22				Installation Complete	Agoura Rd	Westlake Village
10/15/2017 20:09				Installation Complete	Kingspark Ct	Westlake Village
10/15/2017 20:05				Installation Complete	Windsong St	Thousand Oaks
10/11/2017 14:51				Installation Complete	Shenandoah St	Thousand Oaks
10/11/2017 14:47				Installation Complete	Folkestone Terrace	Westlake Village
10/11/2017 13:15				Installation Complete	Jean Lane	Westlake Village
10/6/2017 15:22				Installation Complete	Via Lara	Newbury Park
10/4/2017 19:03				Installation Complete	Capella Way	Thousand Oaks
10/4/2017 18:30				Installation Complete	Velarde Dr	Thousand Oaks
10/4/2017 18:30				Installation Complete	Amarelle St	Thousand Oaks
10/4/2017 11:49				Installation Complete	Calle Rochelle	Thousand Oaks
10/3/2017 8:50				Installation Complete	Cambridge Ct	Agoura Hills
10/3/2017 8:49				Installation Complete	Blue Meadow Lane	Westlake Village
10/3/2017 8:45				Installation Complete	Huron Ct	Moorpark
9/26/2017 22:51				Rejected by RATES	N/A	N/A
9/25/2017 15:44				Installation Complete	Benchley Ct	Westlake Village
9/25/2017 12:48				Rejected by RATES		Westlake Village
9/21/2017 9:31				Installation Complete	Storm Cloud St	Thousand Oaks
9/15/2017 10:16				Installation Complete	Secret Hollow Lane	Thousand Oaks
9/12/2017 15:41				Installation Complete	Hillview Ave	Los Altos

Modified	Full Name	Home Phone	Email Address	Status	Address	City
9/12/2017 11:01				Rejected by RATES	Navajo Way	Thousand Oaks
9/8/2017 16:07				Waiting for Participant Application		Thousand Oaks
9/7/2017 17:52				Waiting for Participant Application		
9/7/2017 13:06				Waiting for Participant Application	N/A	
9/7/2017 13:06				Waiting for Participant Application	N/A	
9/7/2017 13:06				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	

Modified	Full Name	Home Phone	Email Address	Status	Address	City
9/7/2017 13:05				Waiting for Participant Application		
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:05				Waiting for Participant Application	N/A	
9/7/2017 13:04				Waiting for Participant Application	N/A	
9/7/2017 13:04				Waiting for Participant Application	N/A	
9/7/2017 13:04				Installation Complete	Corkwood Dr	Moorpark
9/7/2017 13:04				Waiting for Participant Application	N/A	
9/7/2017 13:04				Waiting for Participant Application	N/A	
9/7/2017 13:04				Waiting for Participant Application	N/A	
9/7/2017 13:04				Waiting for Participant Application	N/A	
8/31/2017 12:33				Installation Complete	Tynebourne Ct, Westlake Village, CA 91361	Westlake Village
8/24/2017 18:25				Rejected by RATES	Might be moving in March, we will not have the history!	Westlake Village/Thousand Oaks
8/24/2017 10:15				Installation Complete	Townsend St, Suite 210	San Francisco

Modified	Full Name	Home Phone	Email Address	Status	Address	City
8/22/2017 18:58				New		
8/22/2017 18:53				New		
8/22/2017 18:45				New		
8/18/2017 9:45				New		
8/18/2017 9:21				Installation Complete	Glen Oaks Rd	Thousand Oaks
8/17/2017 9:22				Installation Complete	Darlington Dr	Thousand oaks
8/15/2017 10:07				Installation Complete	Ambergrove Ct	Simi Valley
8/9/2017 15:21				Installation Complete	Goldman Ave	Moorpark
7/11/2017 9:34				Installation Complete	Venus St	Thousand Oaks
7/6/2017 22:11				Installation	Old Conejo Road	Newbury Park
7/6/2017 16:07				New		Agoura
7/6/2017 16:06				New		Thousand Oaks
7/6/2017 16:06				New		Thousand Oaks
7/6/2017 16:06				New		Moorpark
7/6/2017 16:06				Installation	Lombard St Suite D	Thousand Oaks
7/6/2017 16:06				Installation	Trafalgar Pl	Westlake Village
7/6/2017 16:05				New		Moorpark
7/6/2017 16:05				New		
7/6/2017 16:05				New		
7/6/2017 16:05				New		
7/6/2017 16:05				Installation	Agoura Rd	Westlake Village
7/6/2017 16:05				Installation	Calle Plantador	Thousand Oaks
7/6/2017 16:04				New		Hidden Hills

Modified	Full Name	Home Phone	Email Address	Status	Address	City
7/6/2017 16:04				New		Westlake Village
7/6/2017 16:04				New		Thousand Oaks
7/6/2017 16:04				New		
7/6/2017 16:04				New		Westlake Village – The Ridge
7/6/2017 16:04				New		Westlake Village
7/6/2017 16:04				New		Moorpark
7/6/2017 16:01				New		Agoura Hills

Active RATES Pilot Participant List

The following is a list of the participants that are active within the RATES system. It includes information about the devices in these locations and the type of location, i.e., residential or business.

Table B-2: RATES Participant Status Summary

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #327	00:21:b9:02:46:5c					Yes	Yes	5.0.10D		Yes	12/30/2020 16:00
RATES-Participant #323	00:21:b9:02:47:76						Yes	5.0.10Q		Yes	5/9/2020 3:33
RATES-Participant #324	00:21:b9:02:47:81						Yes	5.0.10Q		Yes	5/9/2020 3:04
RATES-Participant #329	00:21:b9:02:46:b8						Yes	5.0.10Q		Yes	5/9/2020 3:25
RATES-Participant #285	00:21:b9:02:33:22	Yes (Declined)	Yes		Yes			5.0.10D		Yes	12/30/2020 16:00
RATES-Participants#00A	00:21:b9:02:12:e4				Yes		Yes	5.0.13		Yes	12/30/2020 16:00
RATES-Participant #175	00:21:b9:02:3e:55	Yes (Series)			Yes		Yes	5.0.10Q	Yes	Yes	4/27/2019 4:59
RATES-Participant #146	00:21:b9:02:32:22				Yes		Yes	5.0.10Q	Yes	Yes	7/12/2019 8:07
RATES-Participant #148	00:21:b9:02:35:46	Yes (Series)	No	Yes			Yes	5.0.10Q	Yes	Yes	7/12/2019 6:44
RATES-Participant #184	00:21:b9:02:35:3c					Yes	Yes	5.0.10Q		Yes	7/18/2019 4:13

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #151	00:21:b9:02:3b:9f	Yes (Disconnected)						5.0.10A		Yes	12/30/2020 16:00
RATES-Participant #180	00:21:b9:02:31:e3		Yes	Yes			Yes	5.0.13	Yes	Yes	7/12/2019 8:38
RATES-Participant #172	00:21:b9:02:36:63		Yes				Yes	5.0.10Q		Yes	7/26/2019 4:17
RATES-Participant #192	00:21:b9:02:34:98	Yes (Series)						5.0.10Q		Yes	7/26/2019 4:55
RATES-Participant #185	00:21:b9:02:3b:ce	Yes (Disconnected)					Yes	5.0.10Q	Yes	Yes	8/17/2019 5:29
RATES-Participant #426	00:21:b9:02:3d:61				Yes		Yes	5.0.10Q		Yes	8/22/2019 10:23
RATES-Participant #196	00:21:b9:02:36:ff	Yes (Series)	Yes				Yes	5.0.10Q		Yes	9/11/2019 9:40
RATES-Participant #193	00:21:b9:02:38:af							5.0.10Q		Yes	9/11/2019 9:45
RATES-Participant #207	00:21:b9:02:32:8a						Yes	5.0.10Q		Yes	9/11/2019 5:48
RATES-Participant #210	00:21:b9:02:3e:83						Yes	5.0.10Q	Yes	Yes	9/11/2019 5:58
RATES-Participant #208	00:21:b9:02:3e:92	Yes (Disconnected)				Yes	Yes	5.0.10Q	Yes	Yes	9/11/2019 9:11
RATES-Participant #215	00:21:b9:02:3b:22	Yes (Disconnected)					Yes	5.0.10Q	Yes	Yes	9/11/2019 9:06
RATES-Participant #254	00:21:b9:02:3f:a1						Yes	5.0.10Q		Yes	12/30/2020 16:00

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #211	00:21:b9:02:36:d3	Yes (Discon-nected)					Yes	5.0.10Q		Yes	9/11/2019 5:32
RATES-Participant #269	00:21:b9:02:39:da						Yes	5.0.10Q		Yes	9/11/2019 9:27
RATES-Participant #248	00:21:b9:02:20:bc	Yes (Discon-nected)						5.0.10Q		Yes	10/3/2019 7:09
RATES-Participant #250	00:21:b9:02:3b:9d							5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #268	00:21:b9:02:39:cc						Yes	5.0.10Q		Yes	10/3/2019 6:56
RATES-Participant #221	00:21:b9:02:16:ba						Yes	5.0.10Q	Vehemently refused	Yes	10/3/2019 6:53
RATES-Participant #236	00:21:b9:02:39:eb	Yes (Discon-nected)					Yes	5.0.10Q	Yes	Yes	10/3/2019 7:03
RATES-Participant #170	00:21:b9:02:40:74						Yes	5.0.10Q		Yes	10/9/2019 6:29
RATES-Participant #283	00:21:b9:02:3e:f5						Yes	5.0.10Q	Yes	Yes	9/11/2019 9:16
RATES-Participant #217	00:21:b9:02:37:de	Yes (Discon-nected)						5.0.10Q		Yes	9/26/2019 1:33
RATES-Participant #218	00:21:b9:02:37:1c						Yes	5.0.10Q		Yes	9/11/2019 8:47
RATES-Participant #212	00:21:b9:02:3e:9d						Yes	5.0.10Q	Yes	Yes	9/11/2019 8:39

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #219	00:21:b9:02:40:5e						Yes	5.0.10Q	Yes	Yes	10/9/2019 7:02
RATES-Participant #155	00:21:b9:02:3b:97						Yes	5.0.10Q	Yes	Yes	7/12/2019 7:41
RATES-Participant #290	00:21:b9:02:40:5d							5.0.10Q		Yes	10/9/2019 6:49
RATES-Participant #158	00:21:b9:02:37:49						Yes	5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #213	00:21:b9:02:40:60						Yes	5.0.10Q		Yes	10/12/2019 8:00
RATES-Participant #209	00:21:b9:02:40:6d						Yes	5.0.10Q		Yes	10/12/2019 8:18
RATES-Participant #195	00:21:b9:02:40:63	Yes (Discon-nected)					Yes	5.0.10Q		Yes	10/12/2019 8:23
RATES-Participant #253	00:21:b9:02:47:df	Yes (Discon-nected)						5.0.10Q		Yes	10/25/2019 1:29
RATES-Participant #262	00:21:b9:02:47:cc						Yes	5.0.10Q	Yes	Yes	10/25/2019 1:37
RATES-Participant #259	00:21:b9:02:47:f9						Yes	5.0.10Q		Yes	10/25/2019 1:32
RATES-Participant #214	00:21:b9:02:40:68						Yes	5.0.10Q		Yes	10/12/2019 7:57
RATES-Participant #173	00:21:b9:02:41:85							5.0.10Q		Yes	11/14/2019 8:06
RATES-Participant #243	00:21:b9:02:41:8d						Yes	5.0.10Q	Yes	Yes	12/30/2020 16:00

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #247	00:21:b9:02:41:cd							5.0.10Q		Yes	11/14/2019 8:18
RATES-Participant #266	00:21:b9:02:41:d9							5.0.10D		Yes	12/30/2020 16:00
RATES-Participant #258	00:21:b9:02:41:67						Yes	5.0.10Q	Yes	Yes	12/30/2020 16:00
RATES-Participant #278	00:21:b9:02:41:df						Yes	5.0.10Q	Yes	Yes	11/14/2019 8:11
RATES-Participant #00B	00:21:b9:02:0b:89						Yes	5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #246	00:21:b9:02:41:da						Yes	5.0.10Q		Yes	11/27/2019 5:57
RATES-Participant #203	00:21:b9:02:41:e1	Yes (Series)						5.0.10Q		Yes	12/7/2019 3:34
RATES-Participant #275	00:21:b9:02:41:5b							5.0.10Q		Yes	12/7/2019 3:49
RATES-Participant #274	00:21:b9:02:42:06							5.0.10Q		Yes	12/7/2019 3:41
RATES-Participant #163	00:21:b9:02:41:de						Yes	5.0.10Q		Yes	12/7/2019 3:46
RATES-Participant #264	00:21:b9:02:41:5d		Yes					5.0.10Q		Yes	12/7/2019 3:37
RATES-Participant #271	00:21:b9:02:41:e6							5.0.10Q		Yes	1/17/2020 9:38
RATES-Participant #206	00:21:b9:02:41:d8						Yes	5.0.10Q	Yes	Yes	1/17/2020 9:12

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #252	00:21:b9:02:41:d4						Yes	5.0.10Q		Yes	1/17/2020 9:16
RATES-Participant #301	00:21:b9:02:41:ce		Yes				Yes	5.0.10Q	Yes	Yes	1/17/2020 9:34
RATES-Participant #299	00:21:b9:02:41:64						Yes	5.0.10Q	Yes	Yes	1/17/2020 9:03
RATES-Participant #297	00:21:b9:02:41:d1					Yes		5.0.10Q		Yes	1/17/2020 8:59
RATES-Participant #300	00:21:b9:02:41:e5						Yes	5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #204	00:21:b9:02:41:8c	Yes Full	Yes	Yes			Yes	5.0.13	Yes	Yes	11/20/2019 3:30
RATES-Participant #291	00:21:b9:02:3f:7a	Yes (Declined)					Yes	5.0.10Q		Yes	1/22/2020 4:10
RATES-Participant #296	00:21:b9:02:3a:90						Yes	5.0.10Q		Yes	1/22/2020 4:22
RATES-Participant #279	00:21:b9:02:19:2f						Yes	5.0.10Q		Yes	1/22/2020 4:03
RATES-Participant #288	00:21:b9:02:42:d3						Yes	5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #298	00:21:b9:02:42:2e						Yes	5.0.10Q		Yes	1/22/2020 3:38
RATES-Participant #303	00:21:b9:02:42:1c						Yes	5.0.10Q		Yes	2/9/2020 2:11
RATES-Participant #308	00:21:b9:02:42:32		Yes					5.0.10Q		Yes	2/9/2020 2:32

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #305	00:21:b9:02:42:0a						Yes	5.0.10Q	Yes	Yes	2/9/2020 2:41
RATES-Participant #304	00:21:b9:02:42:18						Yes	5.0.10Q	Yes	Yes	2/9/2020 2:51
RATES-Participant #281	00:21:b9:02:41:d6						Yes	5.0.10Q		Yes	1/17/2020 9:07
RATES-Participant #154	00:21:b9:02:46:4b							5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #292	00:21:b9:02:46:4e						Yes	5.0.10Q		Yes	2/26/2020 6:11
RATES-Participant #284	00:21:b9:02:46:5b						Yes	5.0.10Q		Yes	3/14/2020 5:31
RATES-Participant #159	00:21:b9:02:3e:3b						Yes	5.0.10Q		Yes	3/27/2020 6:45
RATES-Participant #293	00:21:b9:02:46:4f				Yes		Yes	5.0.10Q	Yes	Yes	2/26/2020 6:14
RATES-Participant #310	00:21:b9:02:42:36							5.0.10Q		Yes	3/27/2020 6:52
RATES-Participant #267	00:21:b9:02:39:bd						Yes	5.0.10Q		Yes	3/27/2020 7:05
RATES-Participant #306	00:21:b9:02:40:cf						Yes	5.0.10Q		Yes	3/27/2020 6:59
RATES-Participant #313	00:21:b9:02:40:e6						Yes	5.0.10Q		Yes	3/27/2020 6:39
RATES-Participant #307	00:21:b9:02:42:9f						Yes	5.0.10Q		Yes	3/27/2020 7:15

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #314	00:21:b9:02:40:07						Yes	5.0.10Q		Yes	9/25/2019 14:56
RATES-Participant #315	00:21:b9:02:3d:b5						Yes	5.0.10Q	Yes	Yes	3/27/2020 6:23
RATES-Participant #316	00:21:b9:02:3d:86						Yes	5.0.10Q	Yes	Yes	3/27/2020 5:52
RATES-Participant #251	00:21:b9:02:42:b8						Yes	5.0.10Q	Yes	Yes	3/27/2020 5:19
RATES-Participant #237	00:21:b9:02:47:be						Yes	5.0.10Q		Yes	3/27/2020 7:28
RATES-Participant #317	00:21:b9:02:44:e3						Yes	5.0.10Q		Yes	3/27/2020 7:35
RATES-Participant #150b	00:21:b9:02:43:01	Yes (Discon-nected)	Yes					5.0.10Q		Yes	3/27/2020 7:10
RATES-Participant #318	00:21:b9:02:40:fb						Yes	5.0.10Q		Yes	4/11/2020 3:34
RATES-Participant #319	00:21:b9:02:45:ea							5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #322	00:21:b9:02:47:83						Yes	5.0.10Q		Yes	12/30/2020 16:00
RATES-Participant #320	00:21:b9:02:45:f2						Yes	5.0.10Q		Yes	2/26/2020 6:21
RATES-Participant #321	00:21:b9:02:47:88						Yes	5.0.10Q		Yes	5/9/2020 3:11
RATES-Participant #328	00:21:b9:02:45:e9							5.0.10Q		Yes	2/21/2020 7:09

Alias	UUID	Pool	Solar	Storage	Electric Vehicle	Small or Medium Business	Online	Firmware Version	Accepted Phase II	License Active	License Expiry
RATES-Participant #325	00:21:b9:02:47:70						Yes	5.0.10Q		Yes	5/9/2020 3:18
RATES-Participant #150	00:21:b9:02:41:14					Yes		5.0.10Q		Yes	3/27/2020 6:02
RATES-Participant #401	00:21:b9:02:47:86							5.0.10D		Yes	12/30/2020 16:00
RATES-Participant #330	00:21:b9:02:47:82							5.0.10Q		Yes	5/9/2020 3:29

APPENDIX C: Regulatory Status Memo

To the RATES team's knowledge, opt-in deployment of RATES will not require significant regulatory approvals except for approval of the RATES Subscription Transactive Tariff by the CPUC. The subscription element of the RATES tariff substantially protects against systemic winners and losers in the transition from the customer's current LSE and DO tariff to the specific RATES tariff for the customer. Moreover, the highly dynamic spot pricing in the RATES system will support and reduce the resource adequacy requirements of the LSE's and the overall grid. Hence this memo focuses on the Advice Letter submitted for the RATES tariff to the CPUC.

RATES Advice Letter Development

After a series of meeting with SCE and the CPUC, in support of implementing the Subscription Transactive Tariff, the RATES team drafted an Advice letter that SCE reviewed and completed, SCE then signed and submitted the letter to the CPUC using its normal procedures. A copy of the Advice letter is available on the SCE web site at https://www1.sce.com/NR/sc3/tm2/pdf/3837-E.pdf.

At the onset of the project, the SCE management involved with the RATES project was not in a position to proceed with the advice letter and experimental tariff. In February 2018, after months of joint work between the SCE team supporting the RATES project and the RATES team, SCE was willing to proceed with the Advice Letter. It was then reviewed and discussed over multiple sessions with the SCE team and CPUC.

The CPUC representative involved in the review of the RATES project and this Advice Letter were:

- Gabriel Petlin – CPUC Grid Planning and Reliability
- Robert Levin – CPUC Energy Division
- Masoud Foudeh – CPUC Retail Rate Design group
- Jonathan Frost – CPUC Regulatory Analyst
- Matthew Iribarne – CPUC Regulatory Analyst

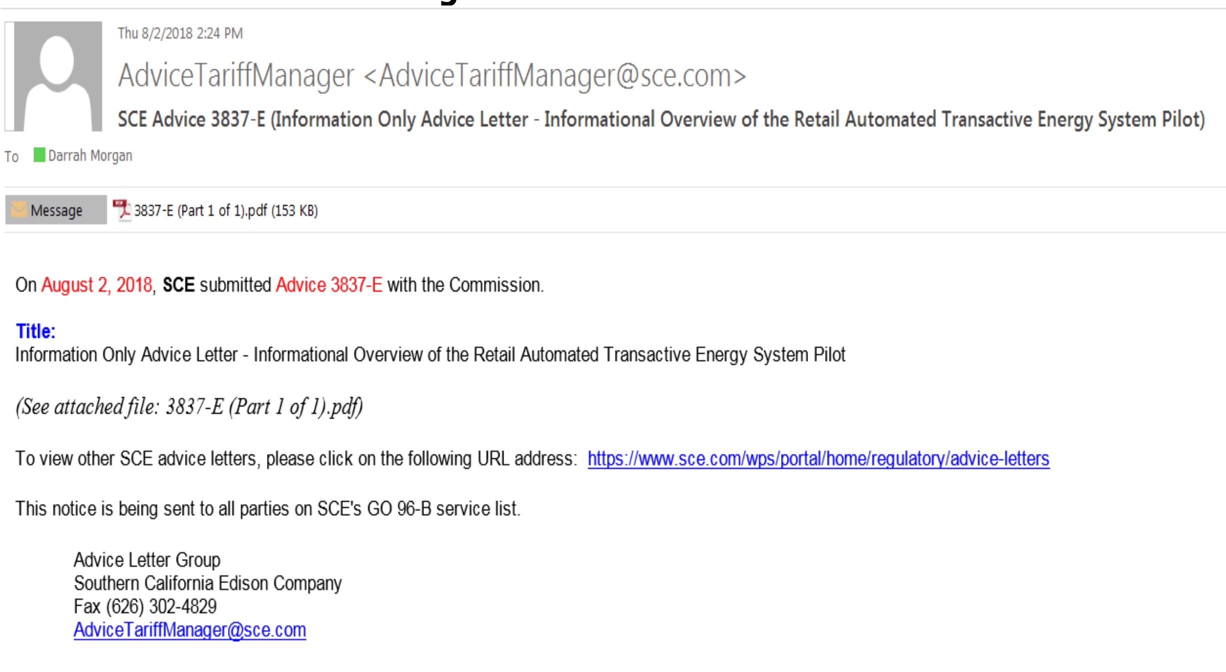
The SCE technical subject matter experts were:

- Mark Martinez – Emerging Markets and Technologies Manager
- Robert Thomas – Pricing Design Manager
- Reuben Behlihomji – Marginal Cost and Sales Forecasting Manager
- Darrah Morgan – Regulatory Operations

The feedback from the multiple review sessions with the CPUC included questions from Bob Levine regarding the SCE cost recovery. Bob also expressed interest in the scarcity pricing curves. Gabe and the RATES team discussed the real-time prices, the baseline, and the subscription quantity. Reuben explained that the ability to analyze all the necessary data is an internal struggle within SCE, and this pilot explores a method of addressing this important topic.

Based on input from the SCE technical team and the legal team, the final version of the Advice Letter was drafted. Darrah Morgan from SCE's Regulatory Affairs and State Regulatory Operations was instrumental with the requirements gathering, the SCE internal legal reviews and the approvals necessary. On August 2nd, 2018, she submitted this advice letter titled Advice Letter 3837-E to the CPUC. (see Appendix H for a full copy of the advice letter. The letter had two inquiries which were responded to by SCE. Below is a screenshot of the SCE submission email.

Figure C-1: Advice Letter 3837-E



Thu 8/2/2018 2:24 PM

AdviceTariffManager <AdviceTariffManager@sce.com>

SCE Advice 3837-E (Information Only Advice Letter - Informational Overview of the Retail Automated Transactive Energy System Pilot)

To Darrah Morgan

Message 3837-E (Part 1 of 1).pdf (153 KB)

On August 2, 2018, **SCE** submitted Advice 3837-E with the Commission.

Title:
Information Only Advice Letter - Informational Overview of the Retail Automated Transactive Energy System Pilot

(See attached file: 3837-E (Part 1 of 1).pdf)

To view other SCE advice letters, please click on the following URL address: https://www.sce.com/wps/portal/home/regulatory/advice-letters

This notice is being sent to all parties on SCE's GO 96-B service list.

Advice Letter Group
Southern California Edison Company
Fax (626) 302-4829
AdviceTariffManager@sce.com

APPENDIX D: Policy and Business Use Case Report

This Appendix outlines some key events in the evolution of the California electricity grid and market to provide a historical policy context for policymaker evaluation of the potential role of Transactive Energy and RATES in addressing the current challenges facing the California electricity sector.

PURPA (1978)

Congress passed the Public Utility Regulatory Policies Act of 1978 (PURPA) to encourage fuel diversity via alternative energy sources and to introduce competition into the electric sector. The Energy Policy Act of 2005 amended PURPA and removed the mandatory purchase obligation on utilities operating in competitive wholesale markets from most qualifying facilities greater than 20 MW.

AB 1890 (1996)

The Electric Utility Restructuring Act (AB 1890) was passed in partial response to large customers wanting direct access to lower-cost electricity than was available from the Investor Owned Utilities (IOUs). The IOUs and other customers were concerned they would bear the "stranded costs" of the generation that would no longer be needed by the IOUs if direct access was allowed for large customers. Under AB 1890, 40 percent of installed capacity was sold to "independent power producers."

In 1996, the California ISO and California Power Exchange (PX) were formed, and the IOUs were required to buy their electricity only from the PX spot market. No new forward contracts were permitted for the IOUs.

In 1996, a private venture formed Automated Power Exchange (APX) to provide both forward markets and spot markets for electric power with the intent to serve both wholesale and retail customers in California. APX was a Transactive Energy system, much like RATES. Despite the fact that APX raised millions of dollars in financing and brought its systems into operation before the PX, the CPUC prevented participation in APX by the IOUs.

The retail rates to customers were frozen until the estimated stranded costs of the IOUs were recovered.

Unfortunately.as a result of low hydro conditions in the Pacific Northwest, high natural gas prices, and other factors, the wholesale prices spiked higher than the frozen retail prices in 2000 and 2001. SCE and PG&E, still with frozen retail prices were paying more at wholesale than they could sell for at retail. The market then collapsed with blackouts and the bankruptcy of PG&E and the PX.

State Contracts, Tiered Rates, Demand Response and Resource Adequacy (2001)

Following the 2001 market collapse, California entered long-term contracts on behalf of the IOUs that were guaranteed by the State and financed by bonds. The higher cost of these contracts was to be recovered mostly from large users by tiered retail rates where the price increases when the customer uses more in a given month. Eventually, Resource Adequacy requirements on the IOUs and others required offering these resources into the California ISO that assumed the spot market from the failed PX.

However, the State has failed to provide a dynamic retail tariff despite spending billions of dollars on "smart meters." Instead, the State has focused for over ten years on mandatory TOU rate design and pilots that are just being deployed. TOU rates cannot solve California's problems and provide a sound foundation for 100 percent clean energy because of their limited pricing range and coarse time granularity.

Solar, 100 percent Clean Energy, and the Distribution System Operator Concept (2018-2045)

The high tiered retail prices and rapid declines in solar costs have encouraged retail adoption of solar energy. Additionally, the wholesale adoption of solar energy based on the renewable portfolio standard has been very successful]. Together these trends are critical to California's 100 percent clean energy and electrification goals for 2045.

However, with more solar, the California ISO has fewer dispatchable resources to respond to mid-day over-supply of generation and massive evening ramps in non-solar generation. Moreover, increasingly, wholesale energy-only prices are near zero.

The Commission has recognized the need for more storage and flexible use of electricity so that the electricity use can better follow available supply. There are both supply-side and demand-side approaches to address this need.

The supply-side approach is to use DR programs and aggregation to bid load adjustments into the California ISO market for dispatch by the California ISO to perhaps get paid for grid services. This approach has been tried for many years and is complex and ineffective.

Another supply-side approach is to create a Distribution System Operator (DSO) that would centrally aggregate such supply for dispatch by the California ISO. Since the distribution system is primarily a radial system, there is little need for a single central operator for the distribution system for all of California or a region.

What may be needed is a distribution operator (DO) that provides open access for all to buy and sell forward active power kW, and in some cases, reactive power kVAR, and a distribution transport service in either direction on a circuit. A DSO is an open access DO plus centralized dispatch of distributed generation and load.

Centralized energy dispatch on the distribution grid is problematic. Distribution system ownership may be municipal and local, so combined central dispatch of multiple circuits does not have value to customers compared to circuit-by-circuit dispatch except in a few cases of a meshed network. Central dispatch of distributed generation and demand response faces many of the same problems as California ISO dispatch of demand response and behind-the-meter storage and other devices. The software for baseline estimation and settlement will be complex and unreliable, and customers often will be unwilling to bid their behind-the-meter devices to the DSO for centralized dispatch, thereby limiting the flexibility available to the DSO. Such a system would be expensive, and little progress on this alternative has been made after several years of work.

An open-access DO plus RATES is a much better alternative for a more effective, low-cost demand-side approach. In this project, we have implemented and tested RATES to carry out a Transactive Energy approach for California. The RATES approach supports decentralized ownership and management of distributed supply and devices loads that the centralized dispatch approach usually associated with a DSO does not.

It is a State and market participant decision to take the next step towards a system that can support its clean energy goals. Given the serious issues of fire liability and the PG&E bankruptcy, it will be difficult for the State not to make another big market design mistake as in 1996 and 2002. Fortunately, the Commission has seen fit to support the development and initial piloting of RATES, so the State now has more alternatives.

APPENDIX E:
ISY and ISY Portal for RATES

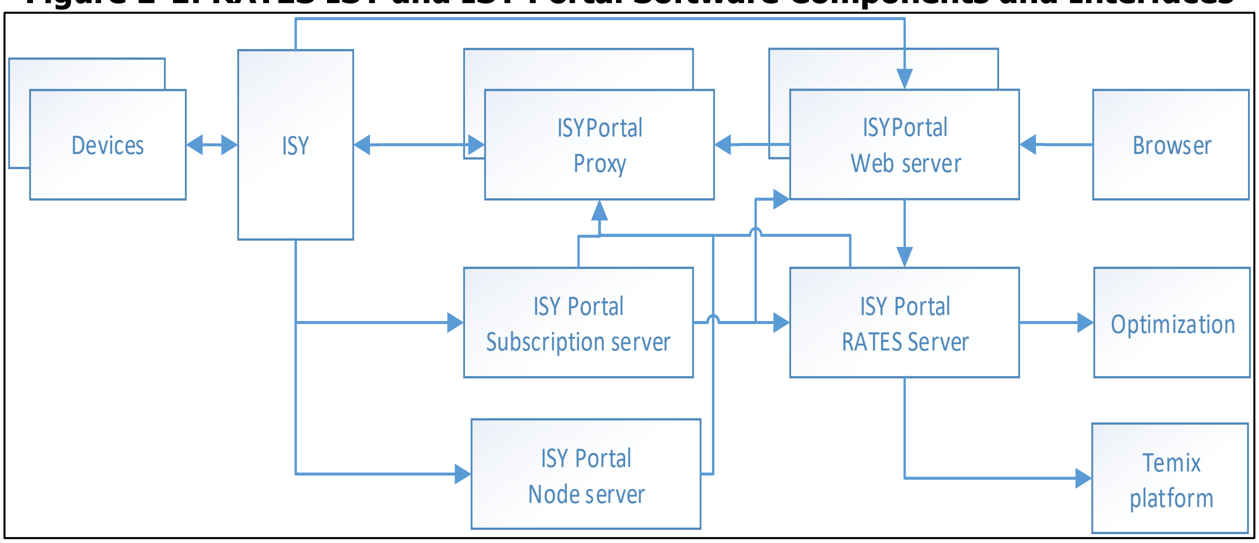
Introduction

ISY994 ZS Series, an autonomous, low cost, off-the-shelf, Smart Grid and IoT based Automation/Energy Management System is utilized to take customer preferences, sensory, Smart Meter/Inverter, DER: Solar(PV)/EV/Storage, Occupancy and Geo-Fencing, and then applying the TeMix Agents algorithm to either automatically shift load usage, or purchase additional energy (at spot prices) while excess energy is credited.

Software Architecture

Figure E-1 is a high-level view of the ISY and ISY Portal software components and interfaces as used by RATES.

Figure E-1: RATES ISY and ISY Portal Software Components and Interfaces



Source: Universal Devices

This document will focus on the ISY Portal RATES Server, but it's important to understand where it fits in the RATES software landscape.

ISY Nodes

Devices such as thermostats, pool pump controller, or the energy meter communicate with the ISY controller over Insteon, Z-Wave, Zigbee or TCP/IP.

Devices on the ISY are represented as nodes.

In addition to physical nodes, we may have virtual nodes which are served by a node server. The ISY Portal has a node server which is used to support occupancy nodes, for example. More on this later.

The project team also used a polyglot server, not represented on this diagram, which supports devices such as Ecobee thermostat, Nest thermostats, and SolarEdge inverters. Those devices have a cloud service which the node server connects to.

A virtual node reacts exactly like a physical node. So, a thermostat communicating with Z-Wave will be controlled the same way as an Ecobee or Nest thermostat.

ISY Portal Proxy Server

Each ISY has a permanent TCP/IP socket opened with one of the ISY Portal proxies. This allows ISY Portal to communicate with each ISY through this server.

ISY Portal Subscription Server

An ISY subscription is a mechanism that allows the ISY Portal to receive every event happening on the ISY. In the case of a thermostat, that could be a local temperature change, a change of mode, setpoint, or the thermostat telling us it is calling for heat.

The ISY Portal has a subscription server that allows it to listen to these events. When active, the ISY has a permanent connection to the subscription server and sends every event.

The RATES server is a client to the subscription server and receives every event for all of the ISYs that are relevant.

ISY portal web server

The browser requests are all directed to the webserver first. Whenever a request is for the RATES server, the request is proxied accordingly. Security is enforced on the webserver though.

Databases

ISY Portal uses MongoDB as a database.

The RATES server uses primarily AWS RDS Aurora service to store data. It also uses the mongoDB collections from ISY Portal when appropriate.

Security

Any request coming from the Internet goes through the webserver. The only exceptions are the connections from the ISY to the proxy server, the subscription server or the node server.

Web Server Security

Web server APIs can authenticate users either using basic auth (regular user and password), or oAuth 2.0 tokens.

oAuth is used for server to server communication for such thing as the cloud polyglot server, Amazon Echo, or Google Home requests.

ISY to Proxy Security

ISYs, when connecting to ISY Portal, first call the dispatcher URL from the webserver (an unauthenticated URL) to get the URL to connect to an available proxy.

When a proxy connection is received, it must respond successfully to a /rest/whoami API, which identifies the ISY UUID.

In order to use an ISY through the proxy, it must first have gone through an approval process which involves the end-user approving access from the account in the ISY Admin Console. This can only be done on the local network.

ISY to Subscription Server Security

When an ISY connects to the subscription server, the ISY UUID is identified. It must match a subscription request to that ISY, which happened in the last few seconds.

ISY to Node Server Security

When configuring a node server, a node server profile configured on ISY, which contains among other things a node server key. This key is required for any requests to the node server by the ISY.

RATES ISY Portal User interface Browser

Account Linking

Pre-requisites:

- ISY Portal user and ISY must have been provisioned in the RATES account/sub-account.
- TeMix account must have been provisioned with a pre-determined certificate fingerprint.

Account linking involves the input of a certificate file and password. The certificate fingerprint must match one entered during the TeMIx account provisioning. Every API calls to the TeMIx platform requires the use of this certificate. This is how authentication is done.

During account linking, the ISY is matched to a TeMix facility ID. The ISY Portal facility data is initialized, and the subscription to the ISY subscription server is started.

Facility Configuration

The facility configuration applies to facility-level parameters. Such parameters include setting the occupancy node, which will allow RATES to detect when the home is occupied or not.

Device Configuration

Every device to optimize must be configured, such as the HVAC (Thermostat) and Pool pump. There is a user-level configuration such as the preferred mode and setpoints when the home is occupied, or not.

To facilitate the configuration, we have an auto-provision button that assists the user in configuring the device. If, for example, there is only one thermostat found, it will be provisioned automatically with default parameters.

There is also RATES administrator advanced configuration parameter to tune the operations of the device. Such parameters include the estimated energy usage when the device runs, for those devices that don’t have an energy meter. To facilitate this configuration, we have a detect button that will cycle the device on and off a few times and detect the instantaneous demand delta before and after. In the case of an HVAC, it will cycle between off and heat up to 5 times, and the same for cooling.

Reports

This allows the end-users to see what is happening, with a granularity of five-minute intervals, or hourly.

RATES User interface Voice

To facilitate operations for the end-users, a RATES Alexa skill has been developed.

At this time, this includes:

- Configuration of HVAC mode, setpoint, and savings level for when home is occupied or not occupied.
- Configuration of Pool pump hours per day and blackout period.
- Get the electricity usage for the past x months/weeks/days/hours/minutes.
- Get a specific device electricity usage for the past x months/weeks/days/hours/minutes.
- Set occupancy to Occupied/Unoccupied
- Ask what is a good time for…

Here's a sample conversation:

> Alexa, tell energy sidekick We're back

Your occupancy status is now set to occupied. Anything else?

> Help

The RATES skill helps you optimize your electricity costs.

To review your smart devices configuration, say "configure my devices."

To let RATES know when home is occupied, say "We are leaving," or "We are back." This allows to set the thermostat based on your at-home or away settings.

To query your global energy costs, ask "what is my electricity costs"

To query the electricity costs for a specific device, ask What is my device electricity cost"

> Configure my devices

The following devices can be configured: AC and Pool pump.

Which device would you like to configure?

> AC

Your at-home preference is to heat at 73 degrees with a savings level set to high. Your away mode is set to off.

To change the mode, say "set AC mode"

To change the preferred set point, say "set AC set point"

To increase the preferred set point "increase AC set point"

To change the savings level say "set AC savings level"

Changing the savings level to high will allows for a higher deviation from your preferred set point when the electricity cost is high.

> Set AC set point

You want to heat up to which temperature?

> 71

Your AC at-home settings is now set to heat at 71 degrees. Anything else?

> Set AC savings level to medium

Your AC at-home savings level was successfully set to medium. Anything else?

> Configure my pool pump

Your pool pump is set to run for 8 hours daily. The blackout period is set from midnight to 7 am next day.

To change the hours per day, say "Set pool pump hours per day"

To change the blackout period, say "Set pool pump blackout period"

> Set pool pump blackout period

Do you want to set a blackout period, or disable it?

> Set

The blackout period is set from midnight to 7 am next day.

What time would you like the blackout period to start?

> 11 pm

What time would you like the blackout period to end?

> 6am

The blackout period is now set from 11 pm to 6 am next day. Anything else?

> What is a good time to run the dishwasher

11 pm or later is a good time. Tomorrow at 6 am or earlier would be even better. Anything else?

> No

RATES Processes

TeMIx Agent Optimization

The purpose of optimization is to figure out when devices should run, given a set of parameters, and forecast the energy usage.

Optimizations are run hourly, for the next 24 hours or so, and every 5 minutes, for the next 2 five-minute intervals.

An optimization will tell us how to control a device, and a schedule is built.

In the case of an HVAC, for every interval optimized, a set point is calculated based on the energy price and the user’s savings level.

In the case of a pool pump, the schedule will be such that it runs according to the user preferences (hours per day, outside of the blackout period), and when the energy prices are at their lowest.

The optimization also tells us how much energy usage is planned, and how much energy should be bought or sold for each interval.

OpenADR Optimization

The project team also experimented with an optimization based on OpenADR price signals.

The OpenADR optimization runs hourly, for the next hour only. It determines if the energy is expensive or cheap based on the history, and controls devices accordingly.

There are no energy transactions done.

Geofencing

Some devices such as HVACs have parameters applicable when home is occupied vs unoccupied. Therefore, an important aspect of the project was to determine that state.

The project team has two methods available:

- Mobile device based
- Alexa

The mobile device approach requires configuration of the Node server, with the UD app on each user's device. Each device will report to the node server (via the webserver) when they are within home's geofence, or outside. If all devices are outside, then home is unoccupied, and unoccupied settings will then be applied.

In addition, the Alexa skill allows the user to tell RATES if home is occupied or not. This works with a node server occupancy node, just like when a mobile device is home or not. In other words, telling Alexa that home is occupied or not has the same effect as having a mobile device within the home geofence, or not.

This approach allows to combine the two methods.

Thermostat operations

The thermostat is controlled through the optimization process.

In ideal circumstances, users should not adjust the thermostat settings directly. Thermostat preferences such as setpoints should be set either through the web interface, under device configurations, or through Alexa.

However, it's very natural for a user to adjust the thermostat directly, so RATES supports the following approach:

If a change in the thermostat physical setpoint from the current optimization set point result is detected, then

If Mode = Cool then set the new preferredCoolSetpont = preferredCoolSetpont +
(new physical set point actual temperature)

If Mode = Heat then set the new preferredHeatSetpont = preferredHeatSetpont +
(new physical set point actual temperature)

Appendix F: The TeMix Platform Service Interfaces

This document provides a detailed technical description of the TeMix Service Interfaces and its communication with the TeMix Platform using the TeMix Services.

For the RATES project, the TeMix Platform is called the Retail Transactive Energy Platform (RTEP)

There are three Service Interfaces to the RTEP (TeMix Platform) for RATES:

- Automated Energy Service Interface (AESI) to the customer facility
- Automated Load Serving Entity Service Interface, and
- Automated Distribution Operator Service Interface

The TeMix Service Interface is an interface to a customer facility is described by Figure F-1. A facility is for a customer, including a prosumer. A facility is a with a home or building or other structure with generation or storage or a distributed, stand-alone generator and storage.

The flow of forward tenders is from the ADSI to the ALSI to the AESI to create an energy tender for delivery at the facility location on a distribution circuit. All tenders flow thought the RTEP (TeMix Platform). Any tenders accepted as transactions by the AESI flow back to the ALSI and ADSI via the TeMix Platform.

RATES creates between 10 and 33 hourly forward energy and transport tenders to the AESI based on the California ISO daily market clearing at about 2 pm each day on the day before. The forward tenders are for the remaining hours of the day, if before 2 pm, and for the remaining hours of the current day plus the 24 hours of the next day. Additionally, five-minute tenders and 15-minute tenders are created based on the California ISO LMP publication schedule. Currently, the Agent only uses a maximum of 24 hourly tenders.

The ALSI and ADSI are described in the main report.

Components of the Automated Energy Service Interface (AESI)

The Automated Energy Service Interface (AESI), as shown in Figure F-1, consists of (1) a *Device Scheduler application*, (2) a *TeMix Agent application,* and (3) a *Transaction Management application*. Each application may be fully or partially be hosted in the cloud or on a local specialized computer such as the UD ISY. This document assumes that all interfaces to the devices, sensors, meters, and external controls are built into the ISY or ISY Portal or equivalent.

The (1) *Device Scheduler application,* for the RATES project, uses the ISY wireless device communication capabilities and interfaces to the facility devices and sensors, the real-time facility meter, and an internet weather service. The interfaces use these scheduling and sensor capabilities TeMix Agent below.

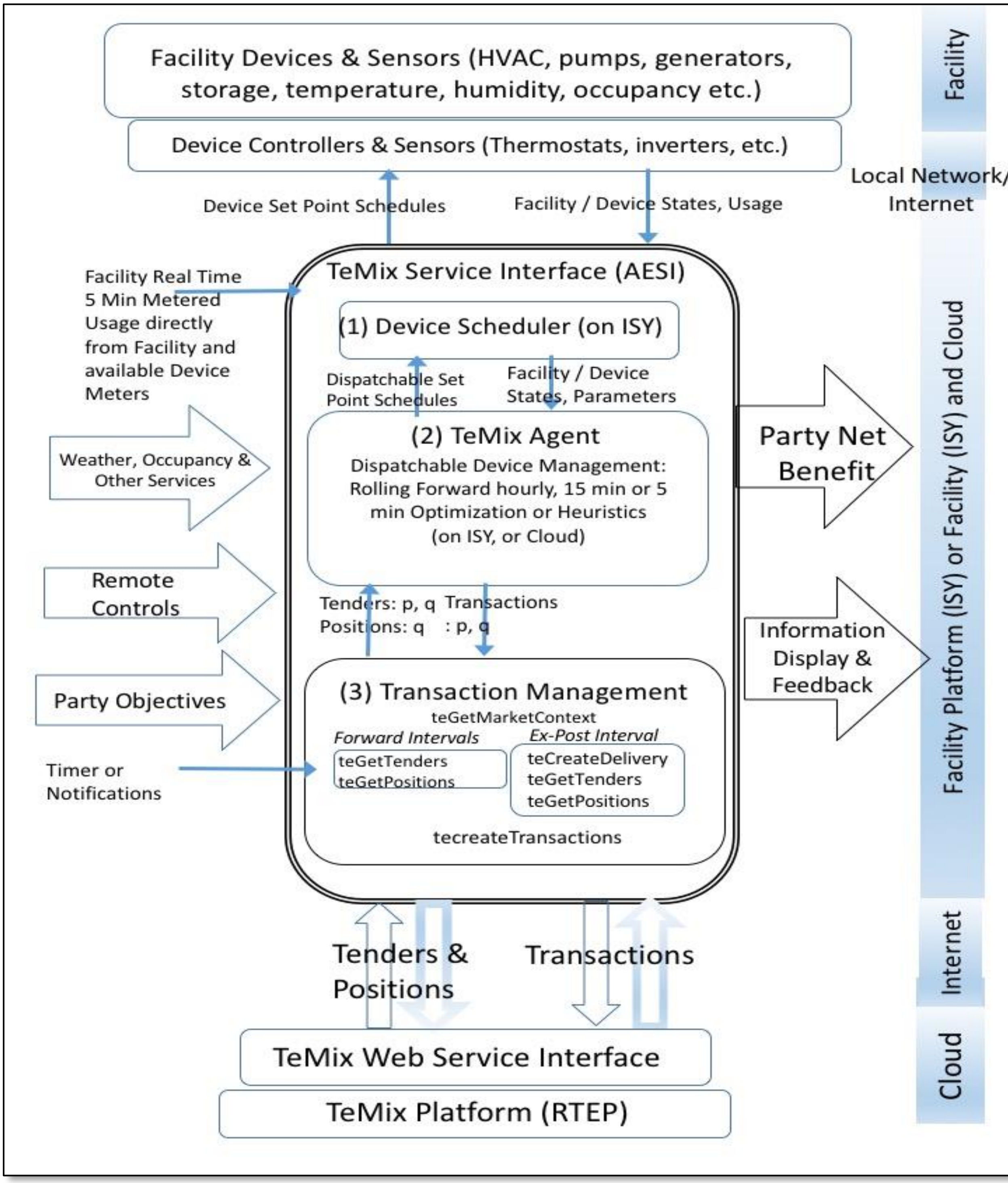
The (2) *TeMix Agent application* manages the schedules for dispatchable devices and in response to the prices and quantities of forward Tenders and the current forward Positions from the TeMix Platform. The outputs of the TeMix Agent are the device schedules and calculation of the buy or sell Transaction quantities for the 24-hour horizon or a horizon of 15- or five-minute intervals. Physically the optimization is either hosted the ISY in the facility, or the computationally intensive portion of the optimization is hosted on a cloud server such as the TeMix Agent on Amazon Web Services (assuming a low latency, reliable and secure connection between the cloud and device/facility). For this pilot, the TeMix Agent was cloud-hosted.

The TeMix Agent is a multi-interval optimization that is a mathematical programming application that maximizes the net benefits to the party of the dispatchable devices. The net benefits are benefits less costs. The benefits are measures of comfort, convenience, and need. The cost is primarily the cost of the electricity based on the prices of the forward tenders received by the TeMix Agent. Examples of the TeMix Agents for HVAC, Pool Pumps, Battery Storage, and Electric Vehicles are described in the main report.

The (3) *Transaction Management application* provides a standard interface to the TeMix Web Service of the TeMix Platform. It applies to all TeMix Service Interfaces (AESI, ADSI, and ALSI).

Figure F-1 describes the two-way flow of information within the AESI.

Figure F-1: Automated Energy Service Interface (AESI)



Source : TeMix Inc.

TeMix Web Services

The Energy Interoperation (EI standard Service names use the verbs "get" and "create" for the following key service:

- teCreateDelivery -Create a Delivery record given meter data
- teCreateTenders Create Tenders to Counter Party

- teCreateTransactions Accept a portion of a Tender
- teGetDeliveries Get the Delivery records for a meter.
- teGetMarketContext Get static parameters that describe the facility, agreements, etc.
- teGetPositions Get the total quantity and extended price from a series of transactions
- teGetTransactions Get the Transaction records
- teGetTenders Get the Tender records
- teRegisterCustomer register a new customer.

Transaction Management

The transaction management process begins with teGetMarketContext to provide static information for the facility. Then the following steps occur:

- Use teGetTenders to get all hourly buy and sell tenders for the up to 24-hour window starting with next hour after the current interval
- Use teGetPositions to get the hourly Position for the up to the 24-hour forward operating window
- Initiate TeMix Agent to optimize device schedules and return the needed quantity (buy or sell) in each forward interval.
- Just before each 5 min interval, use teGetTenders and teGetPostions for the available forward five-minute interval.
- Initiate TeMix Agent to optimize device schedules and return the needed quantity (buy or sell) in each available 5-min forward interval.
- After each five-minute interval closes, get 5-minute meter data and call teCreateDelivery.
- Then use teGetPositions for the five-minute interval for ex-post transactions to close the difference with the five-minute delivery quantity.
- For each interval, as necessary, use teCreateTransactions to accept tenders for the needed quantity (buy or sell).

TeMix Web Service: TeWebService

Further detailed technical description of the TeWeb Services that support RATES is provided below:

Target Namespace:

http://portal.temix.net/teWebServices

Port type ITeMixWebService

1. teCreateDelivery
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teCreateDelivery

Input:

ITeMixWebService_teCreateDelivery_InputMessage (soap12:body, use = literal)

parameters type *teCreateDelivery*

- ❒ createDelivery optional, nillable; type *teCreateDelivery*
- ❒ CumQuantity optional; type *double*
- ❒ DurationID optional; type *int*
- ❒ MeterID optional; type *int*
- ❒ ProductTypeID optional; type *int*
- ❒ Quantity optional; type *double*
- ❒ SourceID optional, nillable; type *string*
- ❒ StartTime optional; type *dateTime*
- ❒ UserTrackingNumber optional; type *int*

Output:

ITeMixWebService_teCreateDelivery_OutputMessage (soap12:body, use = literal)

parameters type teCreateDeliveryResponse

- ❒ teCreateDeliveryResult optional, nillable; type *teCreationResponse*
- ❒ ErrorCode optional; type *int*
- ❒ FailedCreations optional, nillable; type *ArrayOfteCreationError*
- ❒ teCreationError optional, unbounded, nillable; type *teCreationError*
- ❒ ErrorCode optional; type *int*
- ❒ Message optional, nillable; type *string*
- ❒ UserTrackingNumber optional; type *int*
- ❒ Message optional, nillable; type *string*

2. teCreateTenders
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teCreateTenders

Input:

ITeMixWebService_teCreateTenders_InputMessage (soap12:body, use = literal)

parameters type *teCreateTenders*

- ❒ createTenders optional, nillable; type *ArrayOfteCreateTender*
- ❒ teCreateTender optional, unbounded, nillable; type *teCreateTender*
- ❒ AgreementID optional; type *int*
- ❒ DurationID optional; type *int*
- ❒ ExpirationDate optional; type *dateTime*
- ❒ Price optional, nillable; type *float*
- ❒ Quantity optional; type *double*
- ❒ Side optional, nillable; type *string*
- ❒ StartTime optional; type *dateTime*
- ❒ Type optional, nillable; type *string*
- ❒ UserTrackingNumber optional; type *int*

Output:

ITeMixWebService_teCreateTenders_OutputMessage (soap12:body, use = literal)

parameters type teCreateTendersResponse

- ❒ teCreateTendersResult optional, nillable; type *teCreationResponse*
- ❒ ErrorCode optional; type *int*
- ❒ FailedCreations optional, nillable; type *ArrayOfteCreationError*
- ❒ teCreationError optional, unbounded, nillable; type *teCreationError*
- ❒ ErrorCode optional; type *int*
- ❒ Message optional, nillable; type *string*
- ❒ UserTrackingNumber optional; type *int*
- ❒ Message optional, nillable; type *string*

3. teCreateTransactions
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teCreateTransactions

Input:

ITeMixWebService_teCreateTransactions_InputMessage (soap12:body, use = literal)

parameters type teCreateTransactions

- ❒ createTransactions optional, nillable; type *ArrayOfteCreateTransaction*
- ❒ teCreateTransaction optional, unbounded, nillable; type *teCreateTransaction*
- ❒ AcceptQuantity optional; type *double*
- ❒ AcceptTenderID optional; type *int*
- ❒ UserTrackingNumber optional; type *int*

Output:

ITeMixWebService_teCreateTransactions_OutputMessage (soap12:body, use = literal)

parameters type teCreateTransactionsResponse

- ❒ teCreateTransactionsResult optional, nillable; type *teCreationResponse*
- ❒ ErrorCode optional; type *int*
- ❒ FailedCreations optional, nillable; type *ArrayOfteCreationError*
- ❒ teCreationError optional, unbounded, nillable; type *teCreationError*
- ❒ ErrorCode optional; type *int*
- ❒ Message optional, nillable; type *string*
- ❒ UserTrackingNumber optional; type *int*
- ❒ Message optional, nillable; type *string*

4. teGetDeliveries

Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetDeliveries

Input:

ITeMixWebService_teGetDeliveries_InputMessage (soap12:body, use = literal)

parameters type *teGetDeliveries*

- ❒ meterID optional; type *int*
- ❒ sourceID optional, nillable; type *string*
- ❒ startTime optional; type *dateTime*
- ❒ endTime optional; type *dateTime*

Output:

ITeMixWebService_teGetDeliveries_OutputMessage (soap12:body, use = literal)

parameters type teGetDeliveriesResponse

- ❒ teGetDeliveriesResult optional, nillable; type *ArrayOfteDelivery*
- ❒ teDelivery optional, unbounded, nillable; type *teDelivery*
- ❒ CumQuantity optional; type *double*
- ❒ DurationID optional; type *int*
- ❒ MeterID optional; type *int*
- ❒ ProductTypeID optional, nillable; type *int*
- ❒ Quantity optional; type *double*
- ❒ SourceID optional, nillable; type *string*
- ❒ StartTime optional; type *dateTime*

5. teGetMarketContext
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetMarketContext

Input:

ITeMixWebService_teGetMarketContext_InputMessage (soap12:body, use = literal)

parameters type teGetMarketContext

Output:

ITeMixWebService_teGetMarketContext_OutputMessage (soap12:body, use = literal)

parameters type teGetMarketContextResponse

- ❒ teGetMarketContextResult optional, nillable; type *teMarketContext*
- ❒ Accounts optional, nillable; type *ArrayOfteAccount*
- ❒ teAccount optional, unbounded, nillable; type *teAccount*
- ❒ AccountID optional; type *int*
- ❒ AccountName optional, nillable; type *string*
- ❒ AccountName2 optional, nillable; type *string*
- ❒ Agreements optional, nillable; type *ArrayOfteAgreement*
- ❒ teAgreement optional, unbounded, nillable; type *teAgreement*
- ❒ AgreementID optional; type *int*
- ❒ AgreementName optional, nillable; type *string*
- ❒ CounterPartyID optional; type *int*
- ❒ EffectiveDate optional; type *dateTime*
- ❒ ExpirationDate optional; type *dateTime*
- ❒ InterfaceID optional; type *int*

- ❒ MarketID optional; type *int*
- ❒ PartyID optional; type *int*
- ❒ ProductID optional; type *int*
- ❒ SubscriptionPlanID optional; type *int*
- ❒ SubscriptionPlanName optional, nillable; type *string*
- ❒ ThirdPartyID optional; type *int*
- ❒ CounterParties optional, nillable; type *ArrayOfteParty*
- ❒ teParty optional, unbounded, nillable; type *teParty*
- ❒ PartyID optional; type *int*
- ❒ PartyName optional, nillable; type *string*
- ❒ Currencies optional, nillable; type *ArrayOfteCurrency*
- ❒ teCurrency optional, unbounded, nillable; type *teCurrency*
- ❒ CurrencyCode optional, nillable; type *string*
- ❒ CurrencyID optional; type *int*
- ❒ Durations optional, nillable; type *ArrayOfteDuration*
- ❒ teDuration optional, unbounded, nillable; type *teDuration*
- ❒ Duration optional, nillable; type *string*
- ❒ DurationID optional; type *int*
- ❒ Length optional; type *int*
- ❒ Facilities optional, nillable; type *ArrayOfteFacility*
- ❒ teFacility optional, unbounded, nillable; type *teFacility*
- ❒ FacilityID optional; type *int*
- ❒ FacilityName optional, nillable; type *string*
- ❒ InterfaceID optional; type *int*
- ❒ MeterID optional; type *int*
- ❒ PartyID optional; type *int*
- ❒ Interfaces optional, nillable; type *ArrayOfteInterface*
- ❒ teInterface optional, unbounded, nillable; type *teInterface*
- ❒ InjectionNode optional, nillable; type *teNode*
- ❒ NodeID optional; type *int*
- ❒ NodeName optional, nillable; type *string*
- ❒ PNode optional, nillable; type *string*
- ❒ InterfaceID optional; type *int*
- ❒ InterfaceName optional, nillable; type *string*
- ❒ TakeoutNode optional, nillable; type *teNode*
- ❒ NodeID optional; type *int*
- ❒ NodeName optional, nillable; type *string*
- ❒ PNode optional, nillable; type *string*
- ❒ Markets optional, nillable; type *ArrayOfteMarket*
- ❒ teMarket optional, unbounded, nillable; type *teMarket*
- ❒ CurrencyID optional; type *int*
- ❒ MarketID optional; type *int*
- ❒ MarketName optional, nillable; type *string*
- ❒ UnitsID optional; type *int*
- ❒ Meters optional, nillable; type *ArrayOfteMeter*
- ❒ teMeter optional, unbounded, nillable; type *teMeter*
- ❒ GreenButtonUUID optional, nillable; type *string*
- ❒ MeterCode optional, nillable; type *string*
- ❒ MeterCode2 optional, nillable; type *string*

- ❒ MeterID optional; type *int*
- ❒ ParamValueRanges optional, nillable; type *ArrayOfteParamValueRange*
- ❒ teParamValueRange optional, unbounded, nillable; type *teParamValueRange*
- ❒ ApiName optional, nillable; type *string*
- ❒ MaxValue optional; type *int*
- ❒ MinValue optional; type *int*
- ❒ ParamName optional, nillable; type *string*
- ❒ RefParamName optional, nillable; type *string*
- ❒ Units optional, nillable; type *string*
- ❒ Party optional, nillable; type *teParty*
- ❒ PartyID optional; type *int*
- ❒ PartyName optional, nillable; type *string*
- ❒ PartyParams optional, nillable; type *tePartyParams*
- ❒ Parameters optional, nillable; type *ArrayOfteParameter*
- ❒ teParameter optional, unbounded, nillable; type *teParameter*
- ❒ Name optional, nillable; type *string*
- ❒ Units optional, nillable; type *string*
- ❒ Value optional, nillable; type *string*
- ❒ PartyID optional; type *int*
- ❒ Products optional, nillable; type *ArrayOfteProduct*
- ❒ teProduct optional, unbounded, nillable; type *teProduct*
- ❒ ProductID optional; type *int*
- ❒ ProductName optional, nillable; type *string*
- ❒ Units optional, nillable; type *ArrayOfteUnits*
- ❒ teUnits optional, unbounded, nillable; type *teUnits*
- ❒ Units optional, nillable; type *string*
- ❒ UnitsID optional; type *int*

6. teGetPositions

Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetPositions

Input:

ITeMixWebService_teGetPositions_InputMessage (soap12:body, use = literal)

parameters type *teGetPositions*

- ❒ startTime optional; type *dateTime*
- ❒ durationID optional; type *int*
- ❒ numIntervals optional; type *int*

Output:

ITeMixWebService_teGetPositions_OutputMessage (soap12:body, use = literal)

parameters type teGetPositionsResponse

- ❒ teGetPositionsResult optional, nillable; type *ArrayOftePosition*
- ❒ tePosition optional, unbounded, nillable; type *tePosition*

- ❒ AgreementID optional; type *int*
- ❒ DurationID optional; type *int*
- ❒ ExtendedPrice optional, nillable; type *double*
- ❒ NetQuantity optional; type *double*
- ❒ StartTime optional; type *dateTime*

- teGetTenders

Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetTenders

Input:

ITeMixWebService_teGetTenders_InputMessage (soap12:body, use = literal)

parameters type *teGetTenders*

- ❒ startTime optional; type *dateTime*
- ❒ durationID optional; type *int*
- ❒ numIntervals optional; type *int*

Output:

ITeMixWebService_teGetTenders_OutputMessage (soap12:body, use = literal)

parameters type teGetTendersResponse

- ❒ teGetTendersResult optional, nillable; type *ArrayOfteTender*
- ❒ teTender optional, unbounded, nillable; type *teTender*
- ❒ AgreementID optional; type *int*
- ❒ DurationID optional; type *int*
- ❒ ExpirationDate optional; type *dateTime*
- ❒ PartyID optional; type *int*
- ❒ Price optional, nillable; type *float*
- ❒ Quantity optional; type *double*
- ❒ Side optional, nillable; type *string*
- ❒ StartTime optional; type *dateTime*
- ❒ TenderID optional; type *int*
- ❒ Type optional, nillable; type *string*

7. teGetTransactions
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetTransactions

Input:

ITeMixWebService_teGetTransactions_InputMessage (soap12:body, use = literal)

parameters type teGetTransactions

- ❒ beginDate optional, nillable; type *dateTime*
- ❒ beginTransactionID optional; type *int*

❒ durationID optional; type *int*
❒ numTransactions optional; type *int*

Output:

ITeMixWebService_teGetTransactions_OutputMessage (soap12:body, use = literal)

parameters type teGetTransactionsResponse

❒ teGetTransactionsResult optional, nillable; type *ArrayOfteTransaction*
❒ teTransaction optional, unbounded, nillable; type *teTransaction*
❒ AgreementID optional; type *int*
❒ DurationID optional; type *int*
❒ PartyID optional; type *int*
❒ PostDate optional; type *dateTime*
❒ Price optional, nillable; type *float*
❒ Quantity optional; type *double*
❒ Side optional, nillable; type *string*
❒ StartTime optional; type *dateTime*
❒ TenderID optional; type *int*
❒ TransactionID optional; type *int*

8. teGetTenders
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teGetTenders

Input:

ITeMixWebService_teGetTenders_InputMessage (soap12:body, use = literal)

parameters type *teGetTenders*

❒ startTime optional; type *dateTime*
❒ durationID optional; type *int*
❒ numIntervals optional; type *int*

Output:

ITeMixWebService_teGetTenders_OutputMessage (soap12:body, use = literal)

parameters type teGetTendersResponse

❒ teGetTendersResult optional, nillable; type *ArrayOfteTender*
❒ teTender optional, unbounded, nillable; type *teTender*
❒ AgreementID optional; type *int*
❒ DurationID optional; type *int*
❒ ExpirationDate optional; type *dateTime*
❒ PartyID optional; type *int*
❒ Price optional, nillable; type *float*
❒ Quantity optional; type *double*
❒ Side optional, nillable; type *string*
❒ StartTime optional; type *dateTime*
❒ TenderID optional; type *int*

❒ Type optional, nillable; type *string*

9. teRegisterCustomer
Request-response. The endpoint receives a message and sends a correlated message.

SOAP action:

http://portal.temix.net/teWebServices/ITeMixWebService/teRegisterCustomer

Input:

ITeMixWebService_teRegisterCustomer_InputMessage (soap12:body, use = literal)

parameters type teRegisterCustomer

- ❒ regCustomer optional, nillable; type *teRegCustomer*
- ❒ AccountNo optional, nillable; type *string*
- ❒ CustomerAddress optional, nillable; type *teAddress*
- ❒ Address optional, nillable; type *string*
- ❒ Address2 optional, nillable; type *string*
- ❒ City optional, nillable; type *string*
- ❒ Country optional, nillable; type *string*
- ❒ Email optional, nillable; type *string*
- ❒ State optional, nillable; type *string*
- ❒ ZipCode optional, nillable; type *string*
- ❒ CustomerFirstName optional, nillable; type *string*
- ❒ CustomerLastName optional, nillable; type *string*
- ❒ FacilityAddress optional, nillable; type *teAddress*
- ❒ Address optional, nillable; type *string*
- ❒ Address2 optional, nillable; type *string*
- ❒ City optional, nillable; type *string*
- ❒ Country optional, nillable; type *string*
- ❒ Email optional, nillable; type *string*
- ❒ State optional, nillable; type *string*
- ❒ ZipCode optional, nillable; type *string*
- ❒ Fingerprint optional, nillable; type *string*
- ❒ GreenButtonUUID optional, nillable; type *string*
- ❒ ISYID optional, nillable; type *string*
- ❒ LSEID optional; type *int*
- ❒ MeterNumber optional, nillable; type *string*
- ❒ PartyName optional, nillable; type *string*
- ❒ SubstationID optional; type *int*

Output:

ITeMixWebService_teRegisterCustomer_OutputMessage (soap12:body, use = literal)

parameters type teRegisterCustomerResponse

- ❒ teRegisterCustomerResult optional, nillable; type *teRegCustomerResponse*
- ❒ ErrorCode optional; type *int*
- ❒ Message optional, nillable; type *string*
- ❒ PartyID optional; type int

APPENDIX G: TeMix Agent

The TeMix Agent is a multi-interval optimization that is a mathematical programming application that maximizes the net benefits to the party of the dispatchable devices. The net benefits are benefits less costs. The benefits are measures of comfort, convenience, and need. The cost is primarily the cost of the electricity based on the prices of the forward tenders received by the TeMix Agent. The TeMix Agents for HVAC, Pool Pumps, Battery Storage and Electric Vehicles are described below, and examples are provided in the main report.

Each of the Agents determine an optimal forward operating schedule for the devices. For HVAC, the operating schedule is heat or cool temperature set points. For pool pumps, the device is either on or off for a full hour. For battery storage, w1 is the discharge kW and w2 is charge kW. For EVs, w2 is the charge kW. Ww1 and we are the average kW over the interval. If the interval duration is 1 hour, the kWh = kW * 1 hour. If the interval duration is five-minutes, the kWh = kW * 1/12 hour.

In a given interval, a device may need to buy kW (a qs sale by the LSE) or sell kW (a qb buy by the LSE).

The qs and qb for unmanaged devices are based on changes in forecasted usage. Other unidentified devices are lumped into residual usage. Residual usage is also forecasted.

The sum of the qs for each device less the sum of the qs for each device is the net qs for the facility. The required facility buy transaction is the net qs if positive. The required facility sell transaction is minus the net qs, if negative.

HVAC Agent

An API call invokes the HVAC Agent is invoked. There are two types of calls:

1) every hour, several minutes before the turn of the hour, to optimize a multi-hour HVAC schedule. Such calls use hourly forward tenders for up to 23 hours in the future.

2) every 5 minutes, typically during minutes 3, 8, …, 58 of each hour. Such calls are used to choose optimal HVAC settings for the nearest 5-min interval. The calculations are based on the most recent 5-min tender and the last set of hourly tenders for up to 23 hours.

The Agent receives requests and returns responses in JSON format. Typical hourly input and output JSON files look as follows:

{
"callTime": "2019-03-14 13:56:09",
"comment": "TeMix HVAC Optimizer",
"data": {
"alpha": {
"value": 5
},
"comfort": {
"alpha_levels": [
0.03,
0.1,
0.3,
1,
3
],
"method": "stdev",
"slider": 5,
"sprefShift": 0.555556,
"units": "C"
},
"e1": {
"value": 2.269
},
"e2": {
"value": 0.800769
},
"exttemp": {
"dimensions": [
23
],
"value": [
18,
17,
17,
15,
13,
11,
10,
9,
8,
7,
7,
7,
7,
6,
6,
6,
6,
6,
9,
13,
15,
17,
18
]
},
"flow": {
"dimensions": [
23
],
"value": [
1.29157,
1.29157,
1.29157,
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"mode": "heat",
"pb": {
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"value": [
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2.39435,
1.04908,
0.178755,
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0.0728239,
0.0552103,
0.0487649,
0.0455859,
0.0448398,
0.0485452,
0.0865773,
0.213933,
0.126118,
0.0589823,
0.0409084,
0.0253436,
0.00758623,
0.00604807
]
},
"ppref": {
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},
"ps": {
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],
"value": [
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0.146907,
0.792003,
2.08308,
2.39616,
1.05047,
0.179968,
0.0968414,
0.0736875,
0.055919,
0.0494244,
0.0462237,
0.0454741,
0.0492264,
0.0873931,
0.21517,
0.127272,
0.0597732,
0.0414025,
0.0256604,
0.00761244,
0.0060525
]
},
"rollover": {
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"sprefh": {
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  }
},
"facilityId": 3,
"time": 1552571769.6,
"variables": {
  "qb": {
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    "finalValue": [],
    "lower": 0,
    "upper": [
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      15.290533333333334
    ],
    "value": 0
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  "qs": {
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    ],
    "finalValue": [],
    "lower": 0,
    "upper": [
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    "value": 0
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  "w1": {
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    "finalValue": [],
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      0,
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      0,
      0,
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      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
```

```
   0
  ],
  "upper": [
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   1.2515,
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   1.2515,
   1.2515,
   1.2515,
   1.2515,
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   1.2515,
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   1.2515,
   1.2515,
   1.2515
  ],
  "value": [
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   0,
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   0,
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   0,
   0,
   0,
   0,
   0,
   0,
   0,
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   0,
   0,
   0,
   0,
   0,
   0,
   0,
   0,
   0,
   0
  ]
 },
 "w2": {
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  ],
  "finalValue": [],
  "lower": [
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   0,
   0,
   0,
   0,
   0,
   0,
   0,
   0,
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   0,
   0,
   0,
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   0,
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   0,
   0
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  "upper": [
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   1.6985
  ],
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   0,
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      0,
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      0,
      0,
      0,
      0.1183139979839325,
      0.3061540126800537,
      0.2568179965019226,
      0.19900399446487427,
```

Output:

```
{
 "version": "HVAC optimizer v.9.5f of Mar 12, 2019",
 "status": {
  "code": 0,
  "codeText": "Optimization terminated successfully. 16 iterations using 417 function evaluations made.",
  "mode": "heat",
  "heatType": "electric",
  "optTime": "2.099 sec"
 },
 "constraints": {
  "surplus": {
   "finalValue": [
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    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0
   ]
  }
 },
 "objective": {
  "netbenefit": {
   "finalValue": 44.197675
  },
  "cost24": {
   "finalValue": -0.004669
  },
```
```
    0,
    0,
    0,
    0,
    0
   ]
  }
 }
}
```
```
  "stdev": 0.105138,
  "alpha": 3
 },
 "variables": {
  "qb": {
   "finalValue": [
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    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0.199004,
    0,
    0,
    0,
    0,
    0
   ]
  },
  "qs": {
   "finalValue": [
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    0,
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```

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0.118327,
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0,
0,
0,
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0
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},
"w1": {
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},
"w2": {
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0,
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]
},
"s_d": {
"finalValue": [
21.851852,
22.453704,
22.777778,
22.175926,
21.944444,
21.898148,
22.129629,
22.314815,
22.5,
22.175926,
22.222222,
21.898148,
21.944444,
22.777778,
22.824074,
22.731482,
22.638889,
20.648148,
21.203704,
21.527778,
21.759259,
22.777778,
22.777778
],
"description": "Cool or Heat Set Point depending on mode (for backward compatibility only, to be retired)"
},
"HeatSetPoint": {
"finalValue": [
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22.453704,
22.777778,
22.175926,
21.944444,
21.898148,
22.129629,
22.314815,
22.5,
22.175926,
22.222222,
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22.824074,
22.731482,
22.638889,
20.648148,
21.203704,

21.527778,
21.759259,
22.777778,
22.777778
],
"description": "Heat Set Point"
},
"CoolSetPoint": {
"finalValue": [
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25.555556,
25.555556,
25.555556,
25.555556,
25.555556,
25.555556,
25.555556,
25.555556
],
"description": "Cool Set Point"
},
"PredictedIntTemp": {
"finalValue": [
23.59159,
23.49159,
24.224001,
23.934001,
24.393171,
23.932171,
24.245424,
23.730524,
23.912452,
23.349042,
23.512776,
23.005707,
23.153069,
22.777778,
22.824074,
22.731482,
22.638889,
22.349903,
22.56657,
22.706483,
23.101483,
23.427404,
23.882904
],
"description": "Predicted interior temperature"
},
"HeatSetPoint_F": {
"finalValue": [
71.333333,
72.416667,
73.0,
71.916667,
71.5,
71.416667,
71.833333,
72.166667,
72.5,
71.916667,
72.0,
71.416667,
71.5,
73.0,
73.083333,
72.916667,
72.75,
69.166667,
70.166667,
70.75,
71.166667,
73.0,
73.0
],
"description": "Heat Set Point in Fahrenheit"
},
"CoolSetPoint_F": {
"finalValue": [
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.083333,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0,
78.0

],
"description": "Cool Set Point in Fahrenheit"
},
"PredictedIntTemp_F": {
"finalValue": [
74.464862,
74.284862,
75.603202,
75.081202,
75.907708,
75.077908,
75.641763,
74.714943,
75.042413,
74.028275,
74.322997,
73.410273,
73.675524,
73.0,
73.083333,
72.916667,
72.75,
72.229826,
72.619826,
72.871669,
73.582669,
74.169328,
74.989228
],
"description": "Predicted interior temperature in Fahrenheit"
}
},
"advice": {
"current": {
"comfort_level": "high",
"slider": 5,
"alpha": 3,
"stdev": 0.105138,
"cost": -0.004669,
"save": 0,
"message": "OK"
},
"lower": {
"comfort_level": "medium high",
"slider": 4,
"alpha": 1,
"stdev": 0.112014,
"cost": -0.026221,
"save": 0.022,
"message": "OK"
},
"comfort_level_requested": {
"slider": 5,
"description": "high",
"alpha": 3
},
"spref_up": {
"cost": -0.005,
"save": 0.0
},
"spref_down": {
"cost": -0.117,
"save": 0.113
},
"sprefShift": 0.555556,
"units": "C",
"overview": {
"alpha": [
0.03,
0.1,
0.3,
1,
3
],
"cost": [
-0.106,
-0.087,
-0.06,
-0.026,
-0.005
],
"cost_extra": [
0.0,
0.02,
0.046,
0.08,
0.102
],
"stdev": [
0.23019,
0.16867,
0.126777,
0.112014,
0.105138
]
}
}
}

A 5-min HVAC request and response contain similar information but only for a single 5-min interval.

The mathematical optimization algorithm of HVAC schedule minimizes the objective function (which is the total net benefit taken with the minus sign) designed as follows:

f = sum [length of interval] * ([Sell Tender Price] * [kWh sold] [Buy Tender Price] * [kWh bought] + alpha * ([Predicted Interior Temperature] [Preferred Interior Temperature])**2) where the sum is taken over all 5-min and/or hourly time intervals from the current moment to the end of the planning horizon. The terms ([Sell Tender Price] * [kWh sold] [Buy Tender Price] * [kWh bought]) represent the total net dollar cost of running HVAC. The term alpha * ([Predicted Interior Temperature] [Preferred Interior Temperature])**2, where alpha is a positive number, typically in the range from 0.01 to 10, represents the user's feeling of comfort. The user implicitly controls the choice of alpha by requesting a level of comfort from low (then the smallest alpha from a preset range is used) to high (the largest alpha). The greater is alpha, the greater is the contribution of the comfort term in the objective function. When alpha is small, the minimum of the objective function guarantees the lowest net cost of operation, while the Predicted Interior Temperatures may differ more from the Preferred Interior Temperatures (low comfort). Large alpha values lead to mathematical solutions that ensure higher comfort (smaller differences between Predicted and Preferred Temperatures), possibly at a higher net cost.

The above objective function is minimized while subject to certain constraints:

the net position of the device (the total of kWh's sold, bought, and used during each time interval for the device, taken with appropriate signs) is zero;

each of the values of kWh's sold, bought, and used during each time interval are below the limits set in the request (input data)

for each 5-min interval, the solution (the recommended values of the thermostat's Heat Set Point and Cool Set Point) is represented by integer numbers (in Fahrenheit scale);

for each hourly interval, the solution is represented by either integer numbers or mixed numbers whose fractional part is n/12 for some n (in Fahrenheit scale).

The method used to solve the optimization problem is a custom algorithm that utilizes Sequential Least SQuares Programming (SLSQP), sequential linear search to avoid convergence to a less than optimal local solution, and the penalty method to provide integer or factional solutions.

Pool Pump Agent

An API call invokes the Pool Pump Agent once an hour, several minutes before the turn of the hour, to optimize a multi-hour pool pump schedule. Such calls use hourly forward tenders for up to 23 hours in the future. The Agent receives requests and returns responses in JSON format. Typical hourly input and output JSON files look as follows:

Input:


```
{
 "callTime": "2019-03-12 06:56:08",
 "comment": "TeMix Pool Pump Optimizer",
 "constraints": {
  "pumphours": {
   "equal": "reqhours",
   "finalValue": [],
   "formula": "s[17]"
  },
  "surplus": {
   "dimensions": [
    17
   ],
   "equal": 0,
   "finalValue": [],
   "formula": "pos w2 + qs qb"
  }
 },
 "data": {
  "blackout": {
   "value": [
    [
     7,
     11
    ]
   ]
  },
  "e2": {
   "value": 1.37
  },
  "h": {
   "dimensions": [
    17
   ],
   "value": [
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
```

```
    1
  ]
},
"pb": {
  "dimensions": [
    17
  ],
  "value": [
    0.185193,
    0.0722065,
    0.0529031,
    0.0461702,
    0.0330929,
    0.0302202,
    0.0211434,
    0.022691,
    0.0209275,
    0.0372082,
    0.379646,
    1.23412,
    1.62177,
    0.792745,
    0.159171,
    0.0666221,
    0.0549041
  ]
},
"ppref": {
  "value": "0.0"
},
"ps": {
  "dimensions": [
    17
  ],
  "value": [
    0.186601,
    0.0732013,
    0.0535563,
    0.0467062,
    0.0334064,
    0.0305086,
    0.0212495,
    0.0228239,
    0.0209966,
    0.0372517,
    0.380296,
    1.23519,
    1.62336,
    0.793971,
    0.160298,
    0.0673826,
    0.0556386
  ]
},
"reqhours": {
  "value": 8
},
"rollover": {
    "value": 0.179893
  },
  "s0": {
    "value": 2.02185
  },
  "start_time": {
    "value": 7
  }
},
"facilityId": 3,
"formulas": {
  "for(i in 2..17)": {
    "s[i]": {
      "formula": "s[i 1] + h[i] * w2[i] * e2"
    }
  },
  "s": {
    "dimensions": [
      17
    ]
  },
  "s[1]": {
    "formula": "s0 + h[1] * w2[1] * e2 "
  }
},
"objective": {
  "netbenefit": {
    "finalValue": [],
    "formula": sumproduct(qb,pb,h)
sumproduct(qs,ps,h)",
    "type": "maximize"
  }
},
"time": 1552373768.8,
"variables": {
  "qb": {
    "dimensions": [
      17
    ],
    "finalValue": [],
    "lower": 0,
    "upper": [
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
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```

15.290533333333334
],
"value": 0
},
"qs": {
"dimensions": [
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],
"finalValue": [],
"lower": 0,
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15.290533333333334,
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15.290533333333334,
15.290533333333334,
15.290533333333334,
15.290533333333334
],
"value": 0
},
"w2": {
"dimensions": [
1
],
"finalValue": [],
"upper": 0.73,
"value": [
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0,
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0.7300000190734863,
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0.7300000190734863,
0.7300000190734863,
0.7300000190734863,
0,
0,
0,
0,
0,
0,
0
]
}
}
}

Output:

{
"status": {
"code": 0,
"codeText": "The optimal solution has 1 contiguous pump run period",
"version": "Pool Pump optimizer v.4.6c of Mar 9, 2019",
"callTime": "2019-03-14 17:31:29 PST",
"text": "Pool pump has run for 2.202 hr thus far out of 8 required hours. Still 17 hours left until the end of the day.",
"rollover_from_yesterday": 0.179893,
"optTime": "0.456 sec"
},
"objective": {
"netbenefit": {
"finalValue": -0.121
}
},
"variables": {
"qb": {
"finalValue": [
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0
]
},
"qs": {
"finalValue": [
0.0,
0.0,
0.0,
0.0,
0.73,
0.73,
0.73,

      0.73,
      0.73,
      0.73,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0
    ]
  },
  "w2": {
    "finalValue": [
      0.0,
      0.0,
      0.0,
      0.0,
      0.73,
      0.73,
      0.73,
      0.73,
      0.73,
      0.73,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0,
      0.0
    ]
  },
  "s_d": {
    "finalValue": [
      2.02185,
      2.02185,
      2.02185,
      2.02185,
      3.02185,
      4.02185,
      5.02185,
      6.02185,
      7.02185,
      8.02185,
      8.02185,
      8.02185,
      8.02185,
      8.02185,
      8.02185,
      8.02185,
      8.02185
    ]
  },
  "rollover": {
    "finalValue": 0.201743
  }
 }
}

The purpose of the pool pump is to minimize the net cost of pool pump operation expressed as the objective function

f = sum [length of interval] * ([Sell Tender Price] * [kWh sold] [Buy Tender Price] * [kWh bought])

where the sum is taken over all hourly time intervals from the current moment to midnight of the current date (in local time).

above objective function is minimized subject to certain constraints:

The pool pump schedule optimization is subject to certain constraints:

the pump must be scheduled to work for a total specified number of hours on the current date, or as close to that number of hours as possible, with the account of the actual number of hours the pump has worked since the beginning of the day to current moment of time and the rollover hours from the previous day. The rollover which could be zero, positive, or negative is defined as the difference between the actual and the desired number of hours of the pool pump operation on the previous day; the rollover is capped by 1 hr from above or -1 hr from below;

the net position of the device (the total of kWh's sold, bought, and used during each time interval, taken with appropriate signs) is zero;

each of the values of kWh's sold, bought, and used during each time interval is below the limits set in the request (input data);

the pump is not scheduled to run during specified blackout periods (for example, during late night and early morning hours);

the number of contiguous periods of pool pump operation during the day is limited to a specified number, to avoid turning it on and off frequently.

The optimized schedule is generated by a custom algorithm broadly based on linear programming with Integer Decision Variables, subject to the above constraints.

Battery Storage Agent

An API call invokes the Battery Storage Agent. There are types of calls:

1) every hour, several minutes before the turn of the hour, to optimize a multi-hour battery operation schedule. Such calls use hourly forward tenders for up to 23 hours in the future.

2) every 5 minutes, typically shortly before minutes 0, 5, 10, …, 55 of each hour. Such calls are used to plan the optimal battery operation for the nearest 5-min interval. The calculations are based on the most recent 5-min tender and the last set of hourly tenders for up to 23 hours.

The Agent receives requests and returns responses in JSON format. Typical hourly input and output JSON files look as follows:

Input:


```
{
 "comment": "TeMix Battery Optimizer",
 "facilityId": 3,
 "data": {
  "maxCharge": {
   "value": 9.6
  },
  "highCharge": {
   "value": 8.5
  },
  "lowCharge": {
   "value": 1.5
  },
  "currCharge": {
   "value": 1.5
  },
  "targetCharge": {
   "value": 1.5
  },
  "targetTime": {
   "value": 24
  },
  "startTime": {
   "value": 0
  },
  "minSalePrice": {
   "value": 0.1
  },
  "e1": {
   "value": 1
  },
  "e2": {
   "value": 0.9
  },
  "h": {
   "dimensions": [
    23
   ],
   "value": [
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1
   ]
  },
  "pb": {
   "dimensions": [
    23
   ],
   "value": [
    0.129728,
    0.125128,
    0.126274,
    0.124529,
    0.132732,
    0.189644,
    0.337846,
    0.196432,
    0.114722,
    0.0927592,
    0.0847797,
    0.08151,
    0.0652637,
    0.0658575,
    0.0811493,
    0.230612,
    1.04126,
    2.24831,
    1.99936,
```

```
      0.757325,
      0.264157,
      0.218495,
      0.180498
    ]
  },
  "ps": {
    "dimensions": [
      23
    ],
    "value": [
      0.131879,
      0.127243,
      0.128446,
      0.126675,
      0.135003,
      0.192471,
      0.341744,
      0.199625,
      0.116552,
      0.0941552,
      0.0860202,
      0.0826851,
      0.0661038,
      0.066689,
      0.0821617,
      0.232046,
      1.04356,
      2.25215,
      2.0041,
      0.761384,
      0.267834,
      0.221725,
      0.183261
    ]
  }
},
"variables": {
  "qb": {
    "dimensions": [
      23
    ],
    "finalValue": [],
    "lower": 0,
    "upper": [
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334
    ],
    "value": 0
  },
  "qs": {
    "dimensions": [
      23
    ],
    "finalValue": [],
    "lower": 0,
    "upper": [
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334
    ],
    "value": 0
  },
  "w1": {
    "dimensions": [
      23
    ],
    "finalValue": [],
    "lower": [
      0,
      0,
      0,
      0,
      0,
      0,
```

    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0
  ],
  "upper": [
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5,
    5
  ],
  "value": [
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0
  ]
},
"w2": {
  "dimensions": [
    23
  ],
  "finalValue": [],
  "lower": [
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0,
    0
  ],
  "upper": [
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,
    3.5,

```
      3.5,
      3.5,
      3.5,
      3.5,
      3.5,
      3.5,
      3.5
    ],
    "value": [
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0
    ]
   }
  }
}
```


Output:


```
{
 "status":
  {
  "code": 0,
  "codeText": "Optimization terminated successfully.
260 iterations using 6723 function evaluations made.",
  "deviceType": "battery",
  "facilityId": 3,
  "profit24": 16.494,
  "serverTime": "1.178070 sec"
 },

 "variables":
  {
  "charge": {
    "description": "Battery charge at the end of each
interval (kWh)",
    "finalValue": [
      1.5,
      4.65,
      5.35,
      8.5,
      8.5,
      8.5,
      3.5,
      1.5,
      1.5,
      1.5,
      1.503,
      1.63,
      4.78,
      7.93,
      8.5,
      8.5,
      8.5,
      3.5,
      1.499,
      1.5,
      1.5,
      1.5,
      1.5
    ]
   },
   "qb": {
    "description": "Selling energy to network (kW)",
    "finalValue": [
      0,
      0,
      0,
      0,
      0,
      0,
      5.0,
      2.0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      5.0,
      2.001,
      0,
      0,
      0,
      0
    ]
   },
   "qs": {
    "description": "Buying energy from network (kW)",
    "finalValue": [
```

```
        0,
        3.5,
        0.777,
        3.5,
        0,
        0,
        0,
        0,
        0,
        0,
        0.003,
        0.142,
        3.5,
        3.5,
        0.633,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0
      ]
    },
    "w1": {
      "description": "Battery discharging (kW)",
      "finalValue": [
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        5.0,
        2.0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        5.0,
        2.001,
        0,
        0,
        0,
        0
      ]
    },
    "w2": {
      "description": "Battery charging (kW)",
      "finalValue": [
        0,
        3.5,
        0.777,
        3.5,
        0,
        0,
        0,
        0,
        0,
        0,
        0.003,
        0.142,
        3.5,
        3.5,
        0.633,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0
      ]
    }
  },
  "version":
    "Battery optimizer v.1.0a of Feb 9, 2019",
}
```


A 5-min Battery Storage request and response contain similar information but only for a single 5-min interval.

The mathematical optimization algorithm of Battery Storage optimizer maximizes the objective function (the total net benefit) designed as follows:

f = sum [length of interval] * ([Buy Tender Price] * [kWh bought] [Sell Tender Price] * [kWh sold])

where the sum is taken over all 5-min and/or hourly time intervals from the current moment to the end of the planning horizon.

The above objective function is minimized while subject to certain constraints:

the net position of the device (the total of kWh's sold, bought, and used during each time interval, taken with appropriate signs) is zero;

each of the values of kWh's sold, bought, and used during each time interval are below the limits set in the request (input data) the battery charge at any moment is between certain lower and upper limits.

The method used to solve the optimization problem is a custom algorithm that utilizes Sequential Least SQuares Programming (SLSQP) and the penalty method.

Electric Vehicle Agent

An API call invokes the Electric Vehicle (EV) Agent. There are two types of calls:

1) every hour, several minutes before the turn of the hour, to optimize a multi-hour EV schedule. Such calls use hourly forward tenders for up to 23 hours in the future.

2) every 5 minutes, typically shortly before minutes 0, 5, 10, …, 55 of each hour. Such calls are used to choose optimal EV charging behavior for the nearest 5-min interval. The calculations are based on the most recent 5-min tender and the last set of hourly tenders for up to 23 hours.

The Agent receives requests and returns responses in JSON format. Typical hourly input and output JSON files look as follows:

Input:


```
{
 "comment": "TeMix EV Optimizer",
 "facilityId": 3,
 "data": {
  "capacity": {
   "value": 100,
   "description": "total battery capacity, kWh"
  },
  "targetCharge": {
   "value": 75,
   "description": "requested percentage of capacity, 0 to
100"
  },
  "targetTime": {
   "value": 7.5,
   "description": "time in hours since midnight by which
targetCharge should be achieved"
  },
  "h": {
   "value": [
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1,
    1
   ]
  },
  "pb": {
   "value": [
    0.740929,
    0.936949,
    0.472653,
    0.160729,
    0.107722,
    0.0984742,
    0.0853666,
    0.0654264,
    0.0584869,
    0.0541112,
    0.0502913,
    0.0476947,
    0.0475585,
    0.0518502,
    0.0638022,
    0.0571036,
    0.0513423,
    0.0481975,
    0.0422047,
    0.0388692,
    0.0366413,
    0.0390974,
    0.0824029
   ]
  },
  "ps": {
   "value": [
    0.741873,
    0.938034,
    0.473728,
    0.161742,
```

```
      0.108692,
      0.0994175,
      0.0862863,
      0.0661784,
      0.059245,
      0.0548628,
      0.0510111,
      0.0483825,
      0.0482416,
      0.0525853,
      0.0646224,
      0.0578877,
      0.052047,
      0.0488273,
      0.0427289,
      0.0393365,
      0.0370652,
      0.0395632,
      0.0829972
    ]
  }
},
"variables": {
  "qb": {
    "upper": [
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334
    ],
    "value": [
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0
    ]
  },
  "qs": {
    "upper": [
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334,
      15.290533333333334
    ],
    "value": [
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      0,
```

```
      0,
      0,
      0,
      0,
      0,
      0,
      0,
```



```
      0,
      0
    ]
   }
  }
}
```


Output:


```
{
 "status":
  {
  "callTime": "2018-12-26 15:02:47 PST",
  "code": 0,
  "codeText": "Optimal charging schedule has been
generated",
  "cost": 2.806,
  "deviceType": "ev",
  "facilityId": 3,
  "serverTime": "0.307974 sec",
  "version": "TeMix EV optimizer v.1a of Dec 23, 2018"
 },

 "variables":
  {
  "charge": {
    "description": "percentage of maxCharge, 0 to 100",
    "finalValue": [
     40.0,
     40.0,
     40.0,
     40.0,
     40.0,
     40.0,
     40.0,
     41.088,
     47.615,
     54.142,
     60.669,
     67.196,
     73.723,
     80.25,
     86.777,
     90.041,
     90.041,
     90.041,
     90.041,
     90.041,
     90.041,
     90.041,
     90.041
    ]
  },
  "qb": {
    "finalValue": [
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0
    ]
   },
   "qs": {
    "finalValue": [
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     1.116417,
     6.6985,
     6.6985,
     6.6985,
     6.6985,
     6.6985,
     6.6985,
     6.6985,
     3.34925,
     0,
     0,
     0,
     0,
     0,
     0,
     0
```

```
    ]
  },
  "w2": {
    "finalValue": [
      0,
      0,
      0,
      0,
      0,
      0,
      0,
      1.116417,
      6.6985,
      6.6985,
      6.6985,
      6.6985,
      6.6985,
      6.6985,
      6.6985,
      3.34925,
      0,
      0,
      0,
      0,
      0,
      0,
      0
    ]
  }
 },
}
```


A five-minute Electric Vehicle request and response contain similar information but only for a single 5-min interval.

The mathematical optimization algorithm of Electric Vehicle schedule minimizes the objective function (which is the total net benefit taken with the minus sign) designed as follows:

f = sum [length of interval] * ([Sell Tender Price] * [kWh sold] [Buy Tender Price] * [kWh bought])

where the sum is taken over all 5-min and hourly time intervals from the current moment to the target time (the time by which the user requested the EV battery to be charged up to the target level) or by the end of the planning horizon, whichever comes first.

EV optimization is subject to certain constraints:

the net position of the device (the total of kWh's sold, bought, and used during each time interval, taken with appropriate signs) is zero;

each of the values of kWh's sold, bought, and used during each time interval is below the limits set in the request (input data);

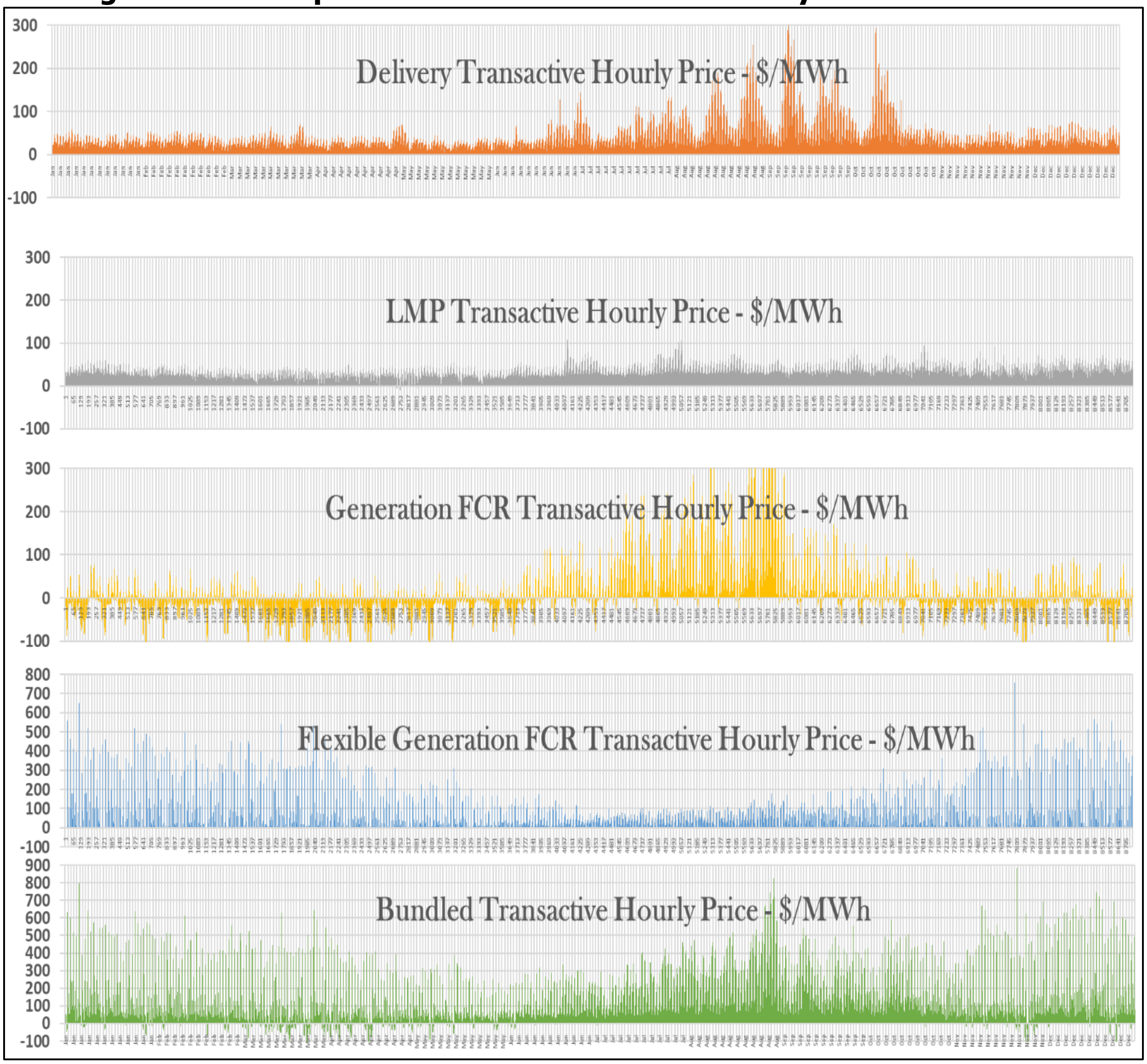
the EV battery level at any moment is between certain lower and upper limits.

The optimized EV charging schedule is generated by a custom algorithm broadly based on linear programming, subject to the above constraints.

APPENDIX H:
Subscription Transactive Tariff Tender Price Calibration

The Subscription Transactive Tariff has four dynamic price components as was described in Chapter 2. Figure H-1 shows the Delivery, LMP, Generation, and Flexible Generation hourly prices for the 2015 test year. Also shown is the bundled hourly price that is the sum of the four component prices.

Figure H-1: Components of Simulated 2015 Hourly Transactive Price



Source: TeMix Inc.

For 2015, the transactive delivery prices are highest when the circuit load is high, especially in the late summer. The 2015 California LMPs are volatile year-round, but in 2015 they are only a modest portion of the 2015 bundled transactive price. With increased renewables in 2019, the LMP price is more volatile. The generation FCR prices are highest in the summer and can be negative in some hours in the spring and fall when net loads may be low. The flexible generation FCR price is highly volatile, especially so, in the winter, spring, and fall when three-hour ramps may be high in the late afternoon and evening, and mid-day air conditioning loads are low.

For delivery, the hourly revenue is the hourly net MW on the circuit times the $/MWh from the delivery scarcity curve (Figure 4).

For generation, the hourly revenue is the hourly net load MW for SCE times the $/MWh from the generation scarcity curve (Figure 5).

For flexible generation, the hourly revenue is the hourly three-hour ramp MW on the circuit times the $/MWh from the flexible generation scarcity curve (Figure 6).

For each of the above three components, the hourly MW is multiplied by the hourly $/MWh to give the hourly revenue. The test year revenue for each component is the sum of the hourly revenues over the 8760 hours of the year.

The scarcity pricing curves were scaled so that the revenues for each component equaled SCEs revenue requirement for each component.

For the pilot during 2018 and 2019, the component prices were calculated using the same curves but actual or forecasted MW for each component. The SCE bundled delivered hourly tender prices is the sum of the LMP, generation, flexible generation and LMP prices. Chapter 3 shows several examples of the 2018 and 2019 hourly bundled tender prices.

Since the 2015 test year is about five years ago the scarcity pricing curves need to be updated using more recent data as soon as possible.

APPENDIX I:
SCE 3837-E Advice Letter

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL® Company

Gary A. Stern, Ph.D.
Managing Director, State Regulatory Operations

August 2, 2018

ADVICE 3837-E
(U 338-E)

PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA
ENERGY DIVISION

SUBJECT: **Information Only Advice Letter**
Informational Overview of the Retail Automated Transactive Energy System Pilot

PURPOSE

The advice letter provides the California Public Utilities Commission (Commission) an overview of the Retail Automated Transactive Energy System (RATES) pilot. Funded by the California Energy Commission (CEC) under a $3.2 million Electric Program Investment Charge (EPIC) grant (GFO-15-311), the RATES pilot is a multi-year experimental retail research study, limited to approximately 100 residential, small and medium commercial customer volunteers. Universal Devices Inc. and TeMix Inc. are the EPIC grant awardees and developers and operators for this study, with informational and technical support provided by Southern California Edison Company (SCE) and the California Independent System Operator (CAISO).

DISCUSSION AND OVERVIEW

SCE customers, recruited by the RATES team, are participating in the EPIC study so that the CEC can better understand how residential, small and medium business electricity customers can self-manage their electrical usage in innovative ways that can reduce their costs, maintain their comfort, while automatically responding to dynamic "buy" and "sell" transactive energy tenders (i.e., priced offers) that reflect the wholesale and retail costs and support the current environmental and economic California policy goals.

The RATES transactive pricing formulas recover the CAISO locational marginal cost, delivery losses and fixed costs, and generation fixed cost not included in the CAISO prices. Participants will be protected from highly variable bills during the RATES study with the rebates because most of their usage is based on a monthly historical subscription and they can possibly benefit from these variable prices by automatically buying when prices are low and selling back when prices are high by shifting and shaping their energy use automatically. The purpose of this proof of concept pilot is to test and demonstrate the participant systems and interfaces, the transactive energy platform, and the interfaces to the distribution, load serving entity and CAISO systems. As illustrated by Figure 1, the buy and sell tenders in the RATES study are developed based on actual market costs from the CAISO, the SCE distribution operator, and the SCE load-serving entity. Communicated and recorded using a Transactive Energy platform by TeMix, the Transactive Energy tenders are sent to each participant who volunteers for the study. The automated energy management system (ISY) by Universal Devices installed in each home processes the tenders, other forecasting information and participant input from the SCE meter. The RATES optimization algorithms propose schedules for operation of specific participant devices such as air conditioners and pool pumps. It also creates buy and sell transactions that are securely recorded on the Transactive Energy platform ledgers.

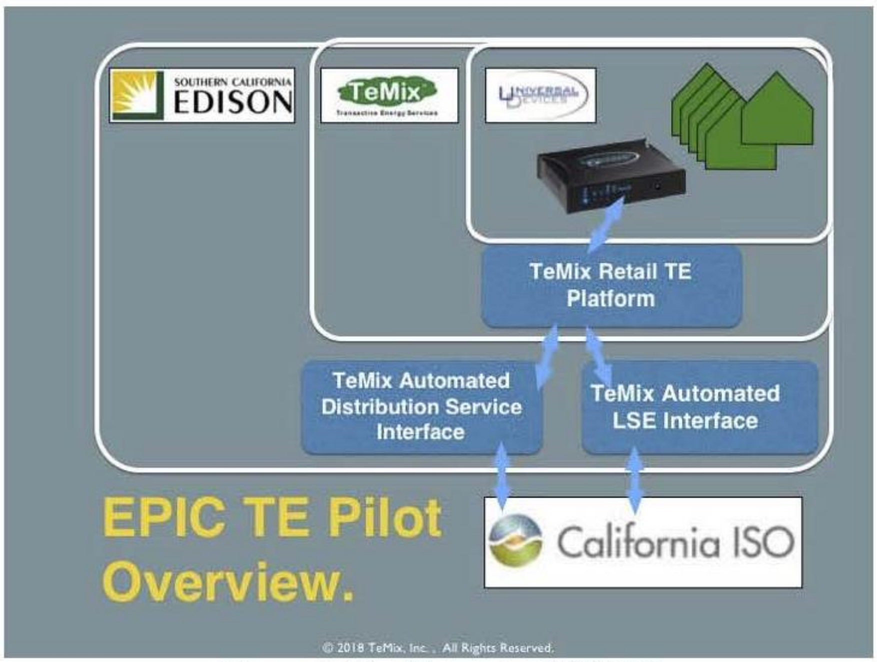


Figure 1: Key Elements of RATES

The RATES study has been designed as an innovative optional rate plan that:

- Stabilizes participant bills and utility revenues using participant specific subscriptions for electricity consumption to ensure recovery of fixed and variable costs for all parties;
- Provides variable pricing for increased and decreased usage from the subscribed hourly kW, typically with automated response to the tenders to benefit the participant; and
- Calculates a monthly bill for the subscription, and the buy and sell transactions that modify the subscription based on the automated response and actual metered usage from the customer.

Participants in the RATES study have entered into a participant agreement (Agreement) with Universal Devices Inc. and TeMix Inc.

The subscription aspect of the Agreement will use historical meter usage data that the participant has agreed to provide for this pilot using SCE's Green Button Third Party Connection Service. The subscription kWh quantity in each hour of a year will be shaped to approximate the participants' historical meter usage. The monthly bill of the subscription will be calculated based on the subscribed hourly quantities and the participant's current SCE otherwise applicable tariff (OAT). Hence if there is no significant change in participant usage during the study, the participant's bill will not significantly change and SCE's revenues will not change.

Participants who volunteer for the study are provided with an OpenADR 2.0 certified energy management system (ISY) and connectivity to the RATES platform. The RATES platform sends day-ahead hourly and 5-minute interval real time buy and sell priced tenders to each participant's energy management system which together with participant preferences are used to help participants manage the operation and costs of operation of their HVAC system, pool pumps, electric vehicle (EV) chargers and other controllable appliances. Additionally, participants are provided with a voice interactive interface to help the participant understand how much they are using and paying for electricity and to set their temperature and other preferences.

The process for determining the RATES monthly bill for the purposes of the research study is illustrated in Figure 2.

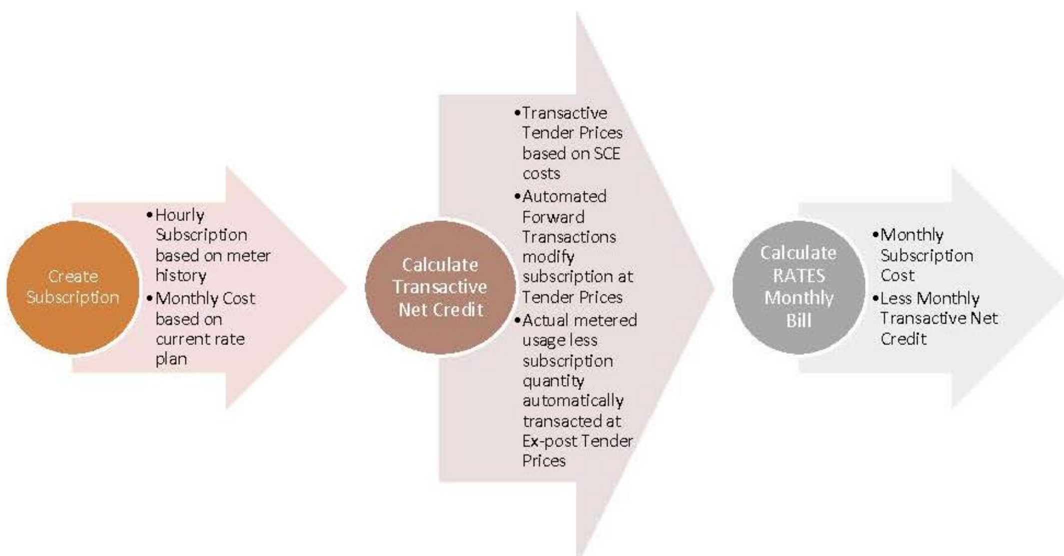


Figure 2: How the RATES Monthly Bill is Determined

The full impact of customer savings in the RATES study cannot be properly tested without actually implementing the Transactive Energy automatic response of the participant's devices to changing prices of electricity. The strategy for this assessment is to allow a participant's RATES energy management system to (1) suggest more cooling, pumping or charging when the transactive tender price from RATES is very low compared to the current SCE OAT price and (2) less cooling, pumping or charging when the transactive tender price is very high compared to the SCE OAT price. Unfortunately, the participant may see a negative benefit of the RATES pilot when the tenders encourage increased usage during lower (or negative) RATES prices due to the current SCE OAT structure, even though both the participant and the overall CAISO system would benefit from the participant's usage as modified and suggested by the RATES tenders.

To resolve this challenge, as illustrated below, a RATES participant rebate process will be developed. Each month the participant will need to continue to pay their regular SCE bill based on their current SCE OAT rate plan, as there is no change to the participants current SCE OAT in the RATES study. As part of the research study, each month the participants will also receive a separate RATES monthly "shadow" bill that they will NOT pay (to illustrate their potential savings). So that participants remain in the study, Universal Devices and TeMix, using project funds from the EPIC grant, will provide the participants rebates each month for possible "excess charges" so they will not pay more than their SCE OAT, and actually potentially less after rebates based on their savings as participants in the RATES pilot.

Figure 3: How the Participant is Billed and Rebated

The RATES study is already active in SCE's territory in its initial stages and the dynamic Transactive Energy tenders (with the rebate processes) are scheduled to commence in July 2018. Universal Devices and TeMix report to the CEC on the results of the study as required by the EPIC grant and such reports will be available to the Commission as requested.

No cost information is required for this advice letter.

This advice letter will not increase any rate or charge, cause the withdrawal of service, or conflict with any other schedule or rule.

TIER DESIGNATION

Pursuant to General Order (GO) 96-B, Energy Industry Rule 5.1, this advice letter is submitted with a Tier 1 designation.

NOTICE

In accordance with GO 96-B, General Rule 6.2, this information-only advice letter is not subject to protest.

In accordance with General Rule 4 of GO 96-B, SCE is serving copies of this advice letter to the interested parties shown on the attached GO 96-B service list. Address change requests to the GO 96-B service list should be directed by electronic mail to AdviceTariffManager@sce.com or at (626) 302-3719. For changes to all other service lists, please contact the Commission's Process Office at (415) 703-2021 or by electronic mail at Process_Office@cpuc.ca.gov.

Further, in accordance with Public Utilities Code Section 491, notice to the public is hereby given by submitting and keeping the advice letter at SCE's corporate headquarters. To view other SCE advice letters submitted with the Commission, log on to SCE's web site at https://www.sce.com/wps/portal/home/regulatory/advice-letters.

For questions, please contact Reuben Behlihomji at (626) 302-6444 or by electronic mail at Reuben.Behlihomji@sce.com.

Southern California Edison Company

/s/ Gary A. Stern
Gary A. Stern, Ph.D.

GAS:rb:cm
Enclosures

CALIFORNIA PUBLIC UTILITIES COMMISSION

ADVICE LETTER SUMMARY
ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No.: Southern California Edison Company (U 338-E)

Utility type:	Contact Person: Darrah Morgan
☑ ELC ☐ GAS	Phone #: (626) 302-2086
☐ PLC ☐ HEAT ☐ WATER	E-mail: Darrah.Morgan@sce.com
	E-mail Disposition Notice to: AdviceTariffManager@sce.com

EXPLANATION OF UTILITY TYPE	(Date Submitted/ Received Stamp by CPUC)
ELC = Electric GAS = Gas	
PLC = Pipeline HEAT = Heat WATER = Water	

Advice Letter (AL) #: 3837-E Tier Designation: 1

Subject of AL: Information Only Advice Letter - Informational Overview of the Retail Automated Transactive Energy System Pilot

Keywords (choose from CPUC listing): Compliance

AL type: ☐ Monthly ☐ Quarterly ☐ Annual ☑ One-Time ☐ Other

If AL submitted in compliance with a Commission order, indicate relevant Decision/Resolution #:

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL:

Summarize differences between the AL and the prior withdrawn or rejected AL:

Confidential treatment requested? ☐ Yes ☑ No

If yes, specification of confidential information:
Confidential information will be made available to appropriate parties who execute a nondisclosure agreement.
Name and contact information to request nondisclosure agreement/access to confidential information:

Resolution Required? ☐ Yes ☑ No

Requested effective date: N/A No. of tariff sheets: -0-

Estimated system annual revenue effect: (%):

Estimated system average rate effect (%):

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected: None

Service affected and changes proposed[1]:

Pending advice letters that revise the same tariff sheets: None

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[1] Discuss in AL if more space is needed.

All correspondence regarding this AL shall be sent to:

CPUC, Energy Division
Attention: Tariff Unit
505 Van Ness Avenue
San Francisco, California 94102
E-mail: EDTariffUnit@cpuc.ca.gov

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Appendix J:
Final Project Fact Sheet

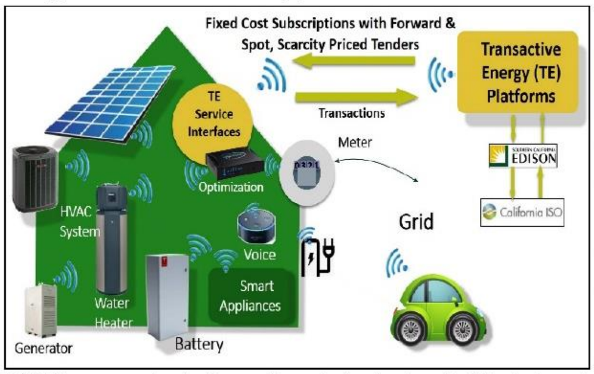
Retail Automated Transactive Energy System (RATES)

California Energy Commission (CEC) - EPIC Grant GFO-15-311
Universal Devices Inc. and TeMix Inc.
Project Fact Sheet
December 31, 2019

California Law requires 100% clean energy by 2045 and increased electrification of building and transport. The goal of this project was to develop and carry out a proof-of-concept pilot of a Retail Automated Transactive Energy System (RATES) that is a demand side-approach that can greatly reduce the costs to customers of achieving the California clean energy and electrification requirements.

The Project

RATES is interfaced with the California ISO and Southern California Edison (SCE). More than 100 SCE residential and small commercial electric customers volunteered for the pilot. Universal Devices Inc. and TeMix Inc. carried out this project from July 2016 to March 2019 under a $3.2 million grant from the California Energy Commission with the support of SCE.



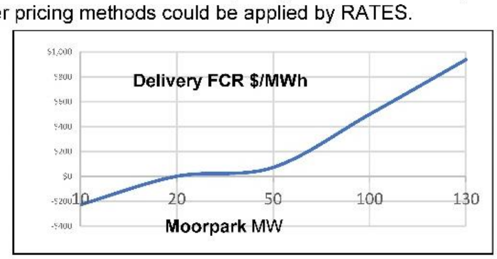
RATES uses a simple, innovative retail rate plan (tariff), designed with support from SCE and the California Public Utilities Commission (CPUC). The tariff offers electric customers "subscriptions" for fixed hourly kW of electricity shaped to their historical usage at a fixed monthly cost. The monthly cost is based on their current tariff[1]. If the customer uses more kW or less kW in an hour than subscribed, RATES automatically sells back kW or buys more kW. The tariff is called a Subscription Transactive Tariff and is designed for low-cost automation and billing.

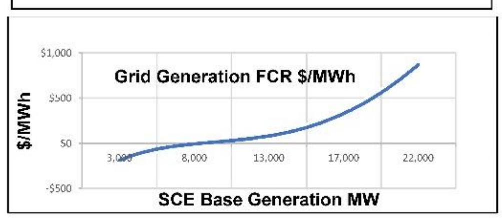
Californians are increasingly using smart home devices, including voice assistants. RATES uses automated agents developed in this project to time-shift electricity use for electric air cooling and heating, electric water heating, electric water pumping, electric vehicle charging, and battery charging. Use shifts to when there is high solar generation and prices are low, and batteries are discharged in time intervals when prices are high because fossil generation is needed. These automated optimization agents act for each customer to manage electric use. Customers can use voice assistants to inform the agents of their preferences for comfort vs. cost, for example, and most use the assistants to set-and-forget.

A Universal Devices energy management system captures actual kW use from the SCE meter for the facility (home) meter and device meters as available in five-minute intervals aligned with the 5-minute intervals used by the California ISO. The 5-minute facility kW and 15-minute kW transmitted from the facility meter to SCE and then to the TE Platform are validated, and any missing 5-minute meter readings are estimated.

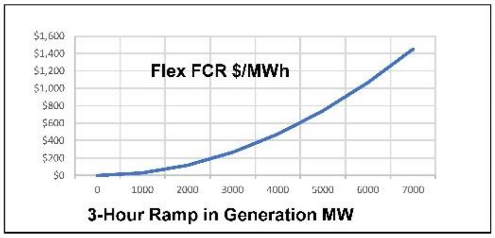
RATES real-time 5-minute, 15-minute, and hourly buy and sell tenders with prices are sent via the internet to the energy management system connected to each managed device. The tender prices are set by an "automated market maker" that works to balance supply and demand in each time interval. The SCE automated market makers set buy and sell prices that recover only regulated costs added to the prices from the California ISO.

The automated market maker uses scarcity pricing curves to calculate the prices that depend on grid conditions. There are currently three curves used by RATES for long-run marginal capital Fixed Cost Recovery (FCR): (1) Delivery FCR for distribution circuit MW in either direction. (2) Generation FCR for bulk generation MW, and (3) Flex FCR for three-hour generation MW increases when solar generation declines, and netload increases, especially in the early evenings. This set of curves was selected to demonstrate the pricing methods for this pilot, and other pricing methods could be applied by RATES.



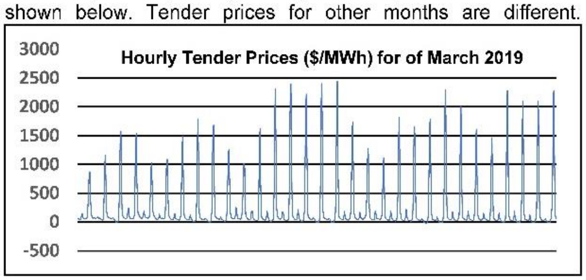


[1] Alternatives for setting up the subscriptions are possible.

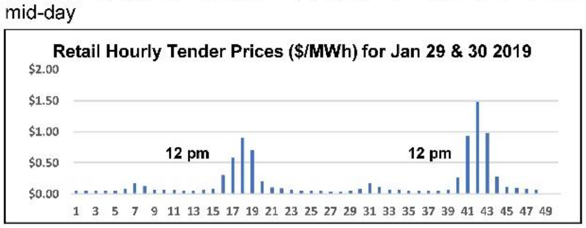


The RATES market maker pricing is a component of the RATES Subscription Transactive Tariff that the CPUC would typically approve.

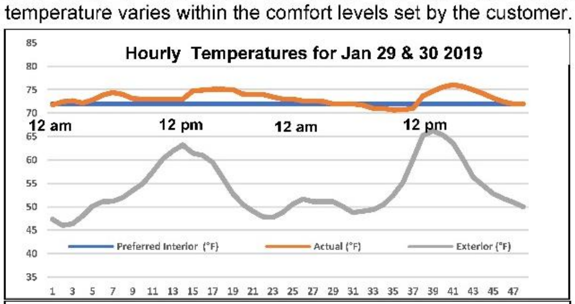
The hourly tender prices ($/MWh) for 31 days of March 2019 are shown below. Tender prices for other months are different.

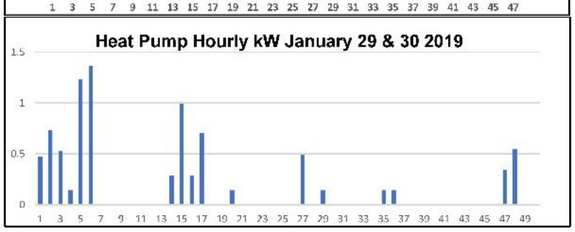


As can be seen the figure above and the figure below for two days in January, the price typically is high in the early evening, and there is a secondary price increase in the early morning and low prices mid-day



For January 29th and 30th 2019, the agent optimized kW input to a heat pump is less when the prices are high; the interior temperature varies within the comfort levels set by the customer.



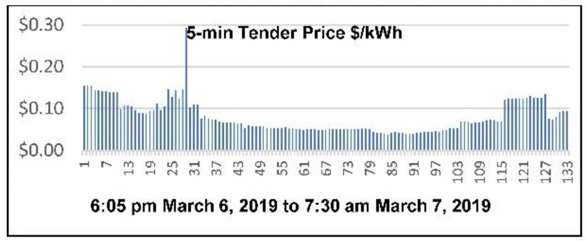


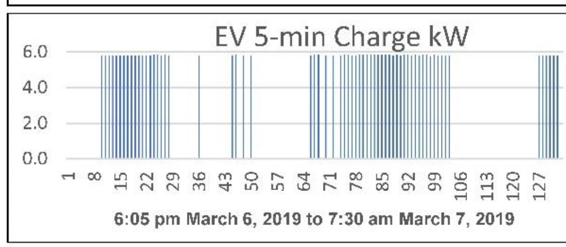
Pool pumps are operated on/off for a full hour, with a maximum of two starts per day or as set by the customer. The agent optimization minimizes the cost to the customer and may be different every day.

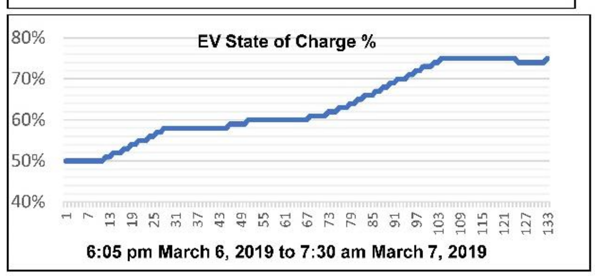
Pool Pump Operation: 8 hours per day – 5 days in January 2019.

Hour	9	10	11	12	13	14
1	[illegible]	0.00	[illegible]	[illegible]	0.00	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	0.00	[illegible]
3	[illegible]	[illegible]	0.00	[illegible]	0.00	[illegible]
4	[illegible]	[illegible]	0.00	[illegible]	[illegible]	[illegible]
5	0.00	0.00	0.00	[illegible]	0.00	[illegible]
6	0.00	0.00	0.00	[illegible]	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	[illegible]	0.00
9	0.00	0.00	0.00	0.00	[illegible]	0.00
10	0.00	0.00	[illegible]	0.00	[illegible]	0.00
11	[illegible]	[illegible]	[illegible]	0.00	[illegible]	[illegible]
12	[illegible]	[illegible]	0.00	0.00	[illegible]	[illegible]
13	[illegible]	[illegible]	0.00	[illegible]	[illegible]	0.00
14	[illegible]	[illegible]	0.00	[illegible]	[illegible]	0.00
15	0.00	[illegible]	0.00	[illegible]	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	[illegible]	0.00	0.00	0.00
23	0.00	0.00	[illegible]	0.00	0.00	0.00
24	0.00	0.00	[illegible]	0.00	0.00	[illegible]

Electric vehicles (EV) are managed based on hourly, 15-minute, and 5-minute tenders. For example, at 6:05 pm on March 6, 2019, the owner plugged the charging cable into a 100 kWh Tesla EV with a 50% state of charge (SOC). The agent automatically began optimizing the charging to achieve 75% SOC by 7:30 am the next day (about 13.5 hours) at least cost, as requested by the owner.







The total cost of the charge was $2.20. The charge added about 82 miles to the range at a retail cost of $0.027 per mile. Importantly, the agent easily avoids charging when the cost to the grid is high and benefits the customer by charging when the cost to the grid is low.

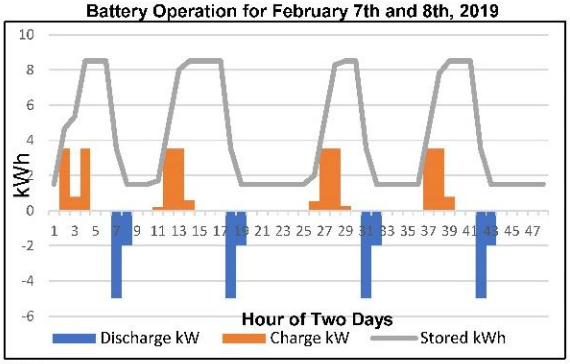
For EV's plugged-in during the day, the optimized charging occurs mid-day when the transactive prices are lowest.

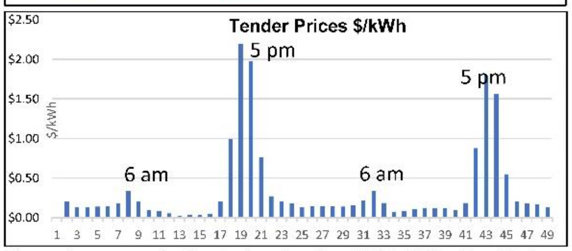
The agent also learns how much discharge occurs in support of the vehicle's system in standby mode. For this EV, the loss of about 3 kWh per day and the agent often can replace this energy at very low or negative 5-minute tender prices saving money for the customer.

A residential battery with a capacity of 9.8 kWh is an excellent example of a RATES agent management. The customer limits the battery to operate between 1.5 kWh and 8.5 kWh to reduce wear on the battery and provide reserve kWh. The maximum discharge rate is 5 kW, and the maximum charge rate is 3.5 kW. The round-trip efficiency is 90%.

RATES typically discharges the battery twice per day at about 6 am and 5 pm. It charges just after midnight and again about noon, with two round trips per day for the battery.

Battery Operation for February 7th and 8th, 2019





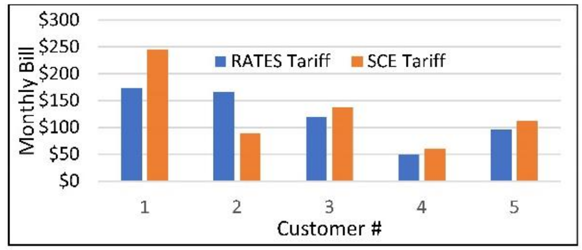
The net revenue for the battery is about $17.00 for the 1st day and $13.50 for the 2nd day. The revenue includes wholesale, distribution (from reversing flow), and ramping revenues. Because of the scarcity pricing curves, both capital and operating costs savings are in the prices and daily savings.

The net revenue for a new battery for a customer is about the same, whether the customer has solar or not, although there are savings in shared inverter capital cost. A solar customer should not experience a significant change in the benefits of solar as the Subscription Transactive Tariff will lock in those benefits. A new solar customer will need to justify the investment based on forecasted or forward transactive prices and any incremental subscription tenders offered.

Each managed device agent determines the change in kW from the optimization for each managed device and the change in forecasted kW for each non-managed device, including a residual virtual device representing all other devices not identified. The change for each device, taking account of whether the change is a buy or sell is summed for all devices to determine the incremental buy or sell kW in each operational interval for the facility. The Agent then uses this facility net buy or net sell to create the necessary new transactions.

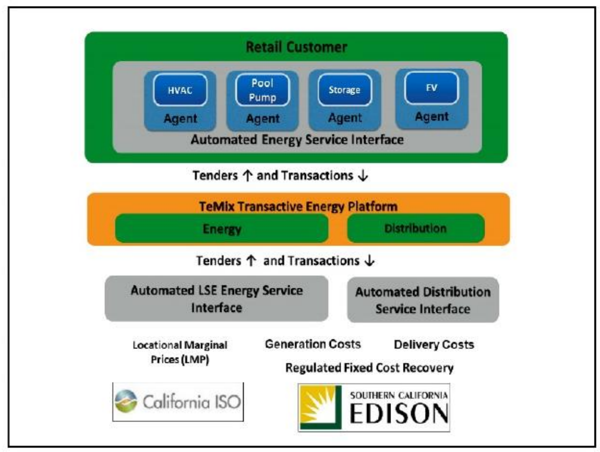
RATES computes the monthly bills for both the RATES and the customer's existing SCE tariff for the same metered usage. For February 2019, the bills for five sample customers varied, as shown below. For one customer, the RATES bill was higher, but for the others, it was lower. Bills vary for many reasons and especially weather and occupancy. More months of operation of RATES with more customers and customers who have more flexible devices are needed for a full understanding of the impact on customer bills.

RATES Bill and SCE Bill for Five Customers for February 2019



Project Timeline

During the first year of the project, the team designed, developed and deployed the RATES hardware and software systems. For over 100 SCE participants, the team installed the Universal Devices energy management system, a communicating thermostat, an Amazon Alexa Voice Assistant and pool controllers where possible. The project also installed three storage batteries with smart inverters. A Tesla EV residential charging system was also interfaced to RATES. The energy management system was commissioned to SCE Smart Meters and the Transactive Energy (TE) Platform.



The project team deployed the TeMix Platform with automated interfaces to the Universal Devices systems, the SCE load-serving entity, the SCE distribution operator, and the California ISO. The Platform was set up for five minute, 15-minute, and hourly electricity transactions with binding terms for physical delivery and payment between the California ISO, the SCE distribution operator, and the SCE load-serving entity and each participant.

Optimization Agents were developed to determine customer device operation based on the RATES tariff, weather, device characteristics, and customer preferences. The energy management system controls the devices based on the optimized device operation and creates buy or sell transactions with SCE using the TE Platform.

All equipment and data feeds were available for continuous, real-time, end-to-end development and testing of RATES with both controlled and simulated control of actual customer devices. Bills were computed for both the RATES tariff and the customer's SCE tariff.

The team developed the Subscription Transactive Tariff and the systems to download historical meter and tariff information for each participant automatically. The team received CPUC, SCE, and customer approvals to apply the experimental tariff late in the project timeline, which limited the number of months it could be applied.

Project Accomplishments

- Developed the end-to-end integrated RATES, the first operational demonstration of a retail automated transactive energy system
- Put the RATES system into continuous 24/7 operation for more than a year.
- With feedback from actual operation, the team continuously improved all RATES systems for throughput, reliability, and effectiveness making many software and hardware improvements
- Obtained approval by SCE and the CPUC of a subscription transactive tariff that provides stable customer bills and revenues while providing highly variable real-time prices as input to the automated operation of customer devices.

RATES Benefits

- RATES can help to meet California's clean energy goals, cost-effectively.
- RATES can be highly beneficial to Californians in comparison to conventional tariffs and supply-side aggregation and demand response programs for storage, EV charging, and HVAC management.
- Customers will benefit from RATES in several ways:
    - Opportunities to reduce bills through better energy management informed and automated by RATES
    - Increased bill stability with electricity subscriptions
    - Targeted subscriptions for low-income customers and fairness
    - Opportunities to monetize the flexibility grid services of energy management, smart appliances and controls, storage and solar technologies including heat pump space conditioning and water heating
    - Opportunities to reduce the cost of electric vehicle charging for the customer
    - Increased transparency for the customer into energy use and costs

RATES Policy and Commercialization

RATES is designed as a low-cost, general platform for retail electricity markets that can be deployed anywhere in regulated and competitive markets. For California, in addition to SCE, PG&E, and SDG&E, RATES could be deployed for any CCA or municipal utility. Interfaced to the wholesale market. RATES is also applicable in most any electricity market, globally.

The team recommends that further deployment of RATES focus on medium and larger retail customers. Customers with electric heat pumps, electric water heating, pumps, battery storage, solar, and electric vehicles are ideal.

Deployment of these electric technologies is in the early stages. Rather than deploying electric technologies as a part of a RATES deployment, both the clean energy and electrification initiatives should provide most of the necessary new electric technologies.

Conclusions and Recommendations

This research achieved its overall goal to develop and pilot-test a complete, low cost and standards-based Retail Automated Transactive Energy System (RATES).

The project highlighted the need for

1. more robust data interfaces between RATES and the SCE meters, the SCE distribution operations, the SCE LSE and the California ISO,
2. more flexible customer devices such as storage, electric vehicles, electric HVAC heat pumps, electric water heaters, and variable speed pool pumps, and
3. a CPUC approved opt-in, Subscription Transactive Tariff.

Several further RATES related research projects are outlined in this report.

The research team's most important recommendation is to initiate the following step-by-step deployment of RATES.

Step 1 - Extend and apply the current RATES pilot for additional research results at reasonable costs including the OpenADR Alliance's work to enhance the Transactive Energy protocols in OpenADR 2.0.

Step 2 - CPUC initiates workshops and rulemaking to implement opt-in Subscription Transactive Tariffs for IOUs and CCAs.

Step 3 – CPUC and CEC initiate a policy process to decide if the Transactive Energy Platforms for the Subscription Transactive Tariff will be:

- Hosted by a not-for-profit public benefit corporation, or
- Hosted by Distribution Operators, LSEs, and private companies.

Step 4 - Deployment of RATES for customers with storage, electric vehicles, and other flexible devices. Tailoring RATES to each customer's situation can reduce deployment costs where the benefits of full RATES deployment are not yet evident.

STEP 5: After a few years of experience with STEP 4 make the Tariff opt-out for most customers.

STEP 6: Enhance the RATES interface to the California ISO to frequently create wholesale tenders and accept aggregated transactions at the substation pNodes.

RATES is an excellent foundation for California retail electricity markets interfaced the California ISO, whether applied by a vertically integrated entity, a distribution operator or a distribution system operator that is transporting electricity for one or more load-serving entities such as CCAs.

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