CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix A: Functional Requirements of the Open Demand Side Resource Integration Platform

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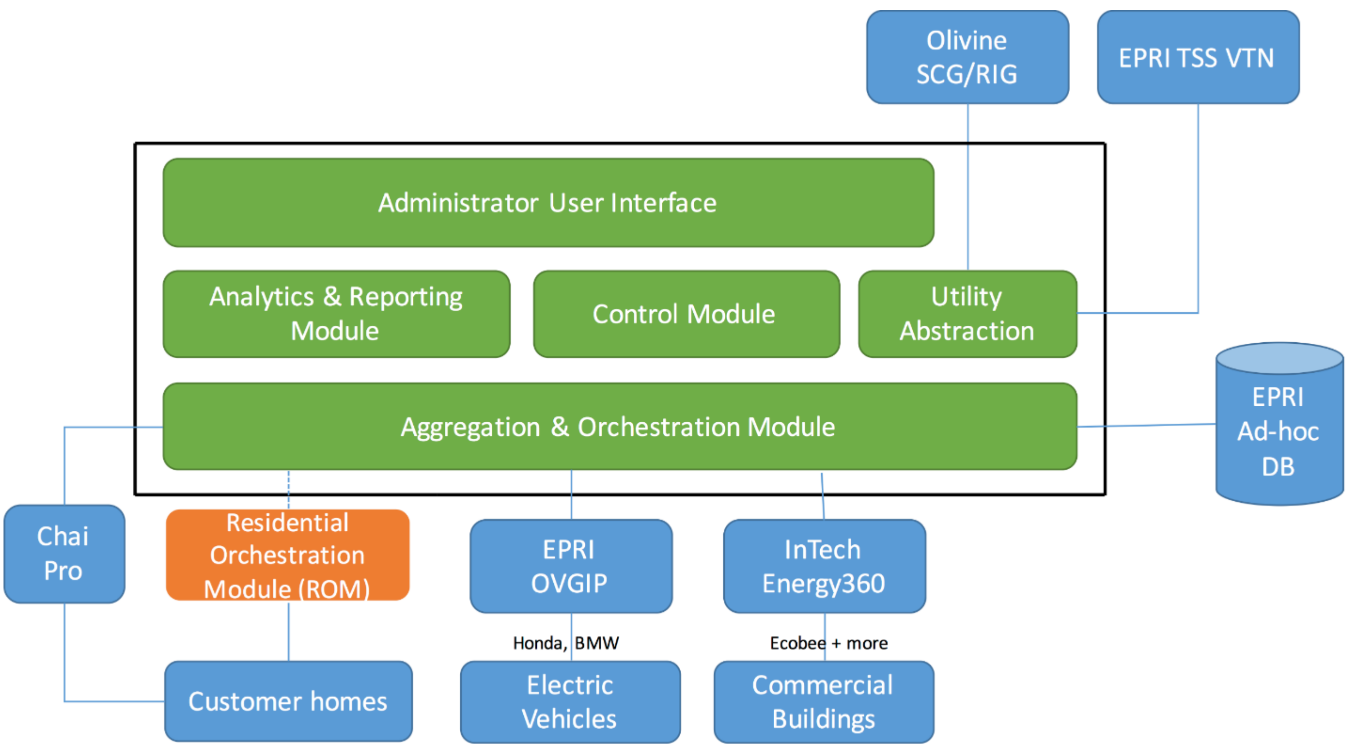
APPENDIX A:
Functional Requirements of the Open Demand Side Resource Integration Platform

This appendix addresses the very first step in the development of OpenDSRIP, namely, the functional and interface requirements that are foundational to the development of the software platform.

Solution Architecture

OpenDSRIP is being developed as a large-scale project combining the best-of-breed "market-based" hardware and software products integrated into a coherent solution. To this effect, the OpenDSRIP was integrated with a class of utility schedules and dynamic DR/Rate Change/TOU systems, commercial BEMS such as Energy360, and EV aggregation platforms such as Open Vehicle Gateway Integration Platform (OVGIP). The proposed OpenDSRIP solution approach is provided in Figure A-1.

Figure A-1: Solutions Architecture for the Open Demand Side Resource Integration Platform



Source: EPRI

The solution will develop two distinct systems, namely, the core DSRIP platform (component shown in Green with a thick black boundary) and an adjunct Residential Orchestration Module (ROM – shown in orange) for control and aggregation of residential communities into the

DSRIP platform. Customer sign-up, registration and customer UI were handled via existing customer UI platforms such as Chai Energy's Chai Pro platform.

DSRIP Component Description

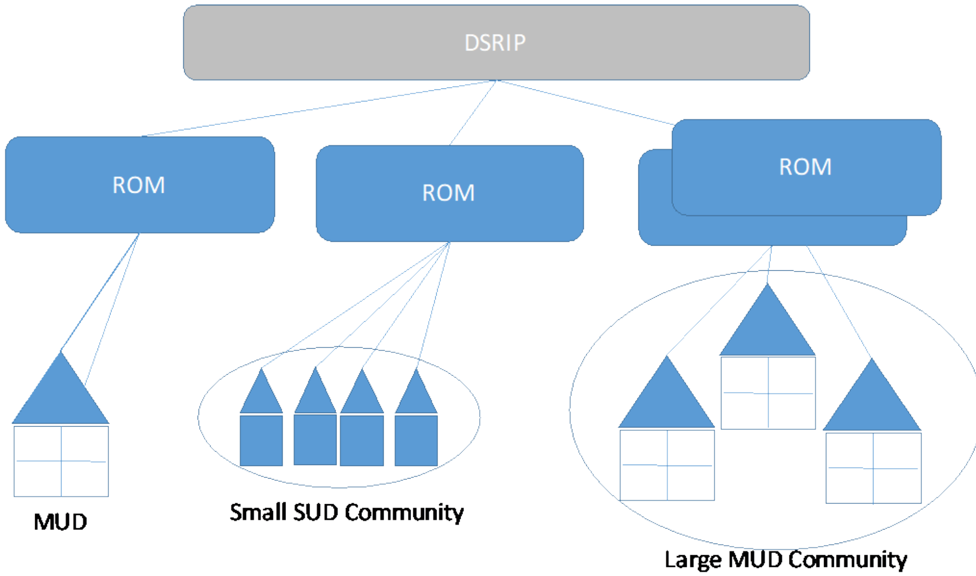
1. **Aggregation and Orchestration** – Provide functionality to aggregate data from various interfacing applications and systems, normalize the data to be able to perform analytic tasks and provide orchestration for tasks that require decomposition of customer-level actions to individual interface actions.
2. **Analytics and Reporting** – Provide functionality to analyze aggregated data for deriving information that is relevant for real-time actions (e.g., understanding real-time response) and long-term behaviors (e.g., energy efficiency). Provide functionality for canned reports.
3. **Utility Abstraction** – Provide the ability to connect to scheduled and transactional pricing systems to initiate DR actions.
4. **Control Module** – Provide a set of high-level control actions that help to drive customer-level actions based on stimuli from scheduled and transactional pricing systems.
5. **Administrator User Interface** – Provides a graphical user interface related to functions for the display of real-time and canned reports as well as the ability to perform ad-hoc database queries for administrators.

Residential Orchestration Module

This is an adjunct module that is outside the development boundaries of the OpenDSRIP platform. This module provides an abstraction for data aggregation across customer homes from multiple end-user devices and customer surveys and is responsible for initiating and orchestrating control actions in response to DR/TOU/rate-change events that arrive from DSRIP in conjunction with customer's preferences that are captured via Chai Pro UI. By keeping the complexity of the variability in individual home devices and user preference-driven control actions outside the boundary of the core DSRIP platform, DSRIP effectively becomes a database of record and an access point for administrative and utility needs while ROM handles the adjunct functions responsible for individual residences.

To allow for scalability while accounting for variations in customer's devices and configurations, ROM is being developed as a hybrid (cloud + collocated EMS). The collocated EMS is one-to-one for each residence but the ROM itself can be one-to-many residences (driven by performance considerations and latency of individual vendor APIs for data acquisition and control action execution). One instance of ROM provides control and data aggregation for a defined number of residences. The number of homes that are under the purview of a single ROM instance depends on performance considerations and was decided as part of a design exercise after the requirements process. However, it is essential to realize that this architecture allows for both Single Unit Dwellings (SUD) and Multi-Unit Dwellings (MUD). Generalized ROM architecture and an instance of ROM for a specific configuration of end-user devices are shown in Figure A-2.

Figure A-2: Residential Orchestration Module Architecture



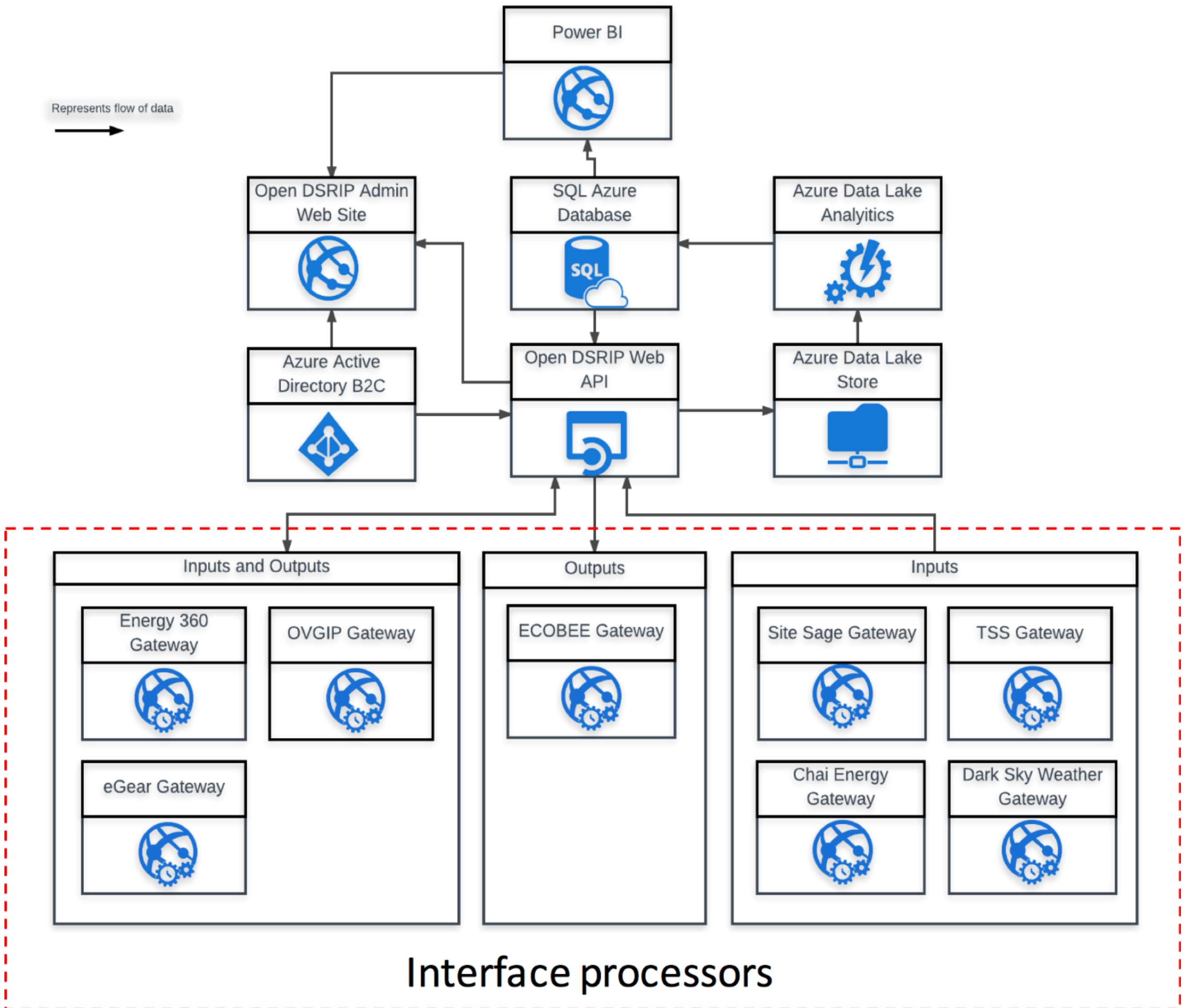
Source: EPRI

System Architectures

The system architecture for DSRIP is shown in Figure A-3. To allow for flexibility in data models and to ensure long-term scalability for the number of customers, variety of end-user devices, and associated data models, the system uses a Microsoft Azure Data Lake based architecture. The highlights of this architecture are:

- System architecture guided by the principle of leveraging best-of-breed technologies
  - Configure COTS functionality
  - Develop custom interface processors
  - Define normalized and abstracted web API
- Microsoft Azure Cloud platform for high reliability and scalability
- High-performance HDFS (Azure Data Lake Store) for transactional data processing.
- Azure Data Lake Analytics provides robust analytics (reactive and predictive)
- SQL Azure database and Power BI for reporting and ad-hoc data queries
- Authenticate, Authorization, and Accounting (AAA) functions are provided through Azure Active Directory.

Figure A-3: System Architecture of the Open Demand Side Resource Integration Platform



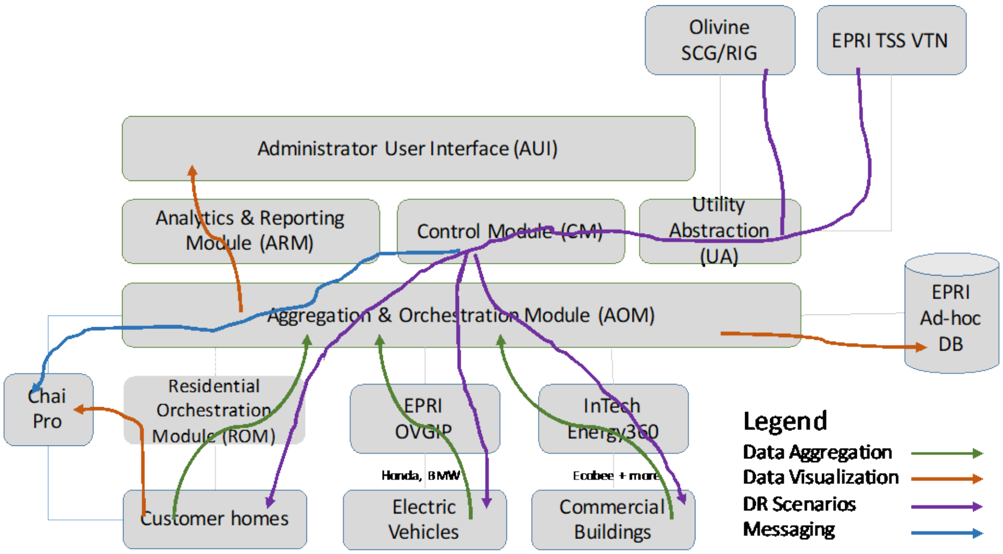
Source: EPRI

Use Cases

Figure A- 4: High-Level System Flows for the Open Demand Side Resource Integration Platform shows OpenDSRIP architecture along with identified high-level flows. A set of use cases are developed in conjunction with each of these high-level flows. Data Aggregation flows are employed to collect micro-level data from residences, commercial facilities, and electric vehicles to support visualization by customers, administrative users and other users. The components involved in Data Aggregation flows are:

- Customer homes → ROM → DSRIP AOM
- EV → OVGIP → DSRIP AOM
- Commercial Facilities → Energy360 → DSRIP AOM.

Figure A-4: High-Level System Flows for the Open Demand Side Resource Integration Platform

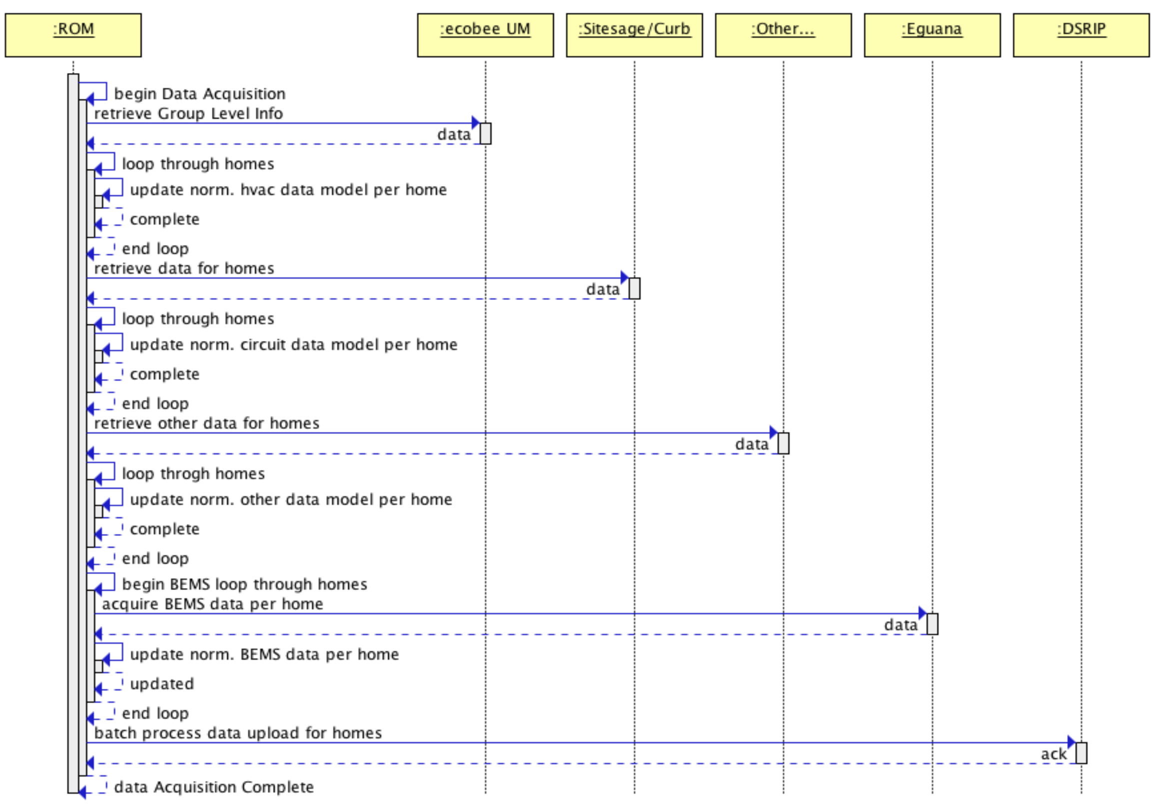


Source: EPRI

Use Case 1: Data Aggregation Flow

Figure A-5 shows the use case definition for ROM posting snapshots of data to DSRIP.

Figure A-5: Residential Orchestration Module Acquires, Normalizes and Posts Snapshots of Residential Data to the Demand Side Resource Integration Platform



Source: EPRI

The overall structure of the use case calls for the acquisition of data from interfacing cloud applications on a periodic (polling) basis and normalizing the data to a pre-defined data model to batch upload the data to DSRIP. The only exception is the case where ROM acquires data from local DER instances such as those found in battery storage or other systems where local energy management systems are available. ROM must acquire the data from each home and then normalize the data. Additionally, while the use case depicts a sequentially executed and single-threaded acquisition from various cloud applications, this can be executed in parallel through a multi-threaded approach.

The use cases for OVGIP and Energy360 to provide data to DSRIP are not subject to development and thus are not shown here. Additionally, a normalized data model for uploading EV and Energy360 data was provided by the development agencies responsible for OVGIP and Energy360 development and was documented in Addendums to this document.

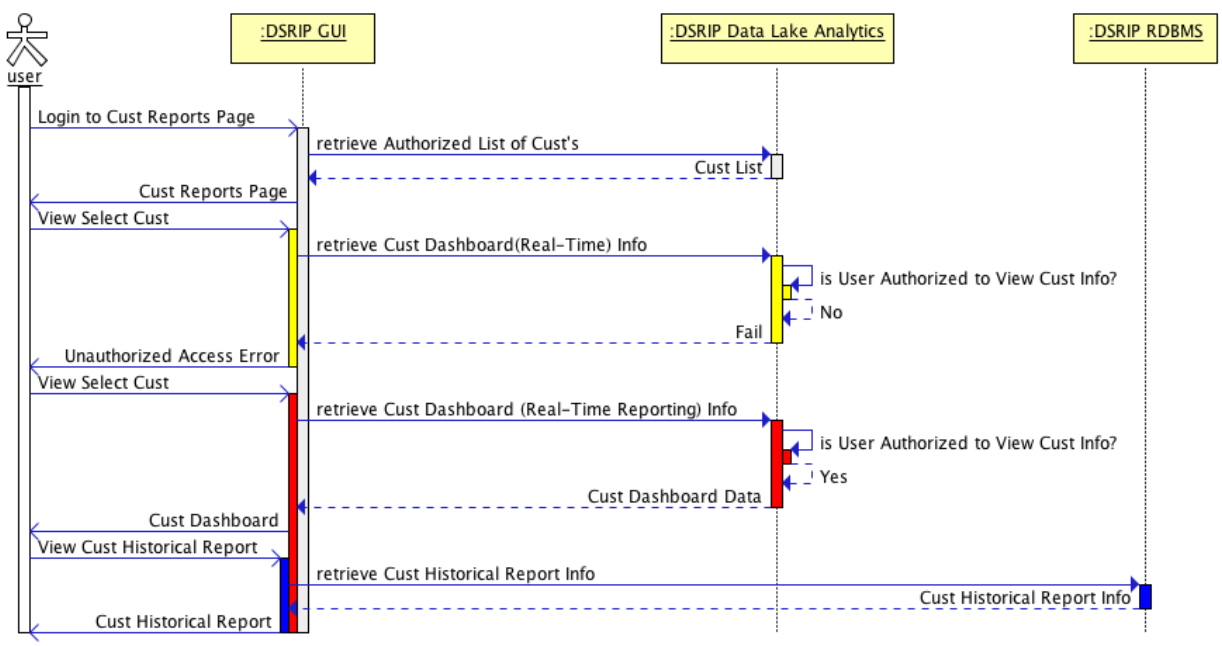
Use Case #2: Data Visualization Flows

Data Visualization flows are used to provide information from the data collected to administrative users, customers and other users who may need ad-hoc access to data for analytic purposes. The components involved in Data Aggregation Flows are:

- Aggregation & Orchestration → Analytics & Reporting → Administrator UI
- Aggregation & Orchestration → EPRI Ad-hoc DB
- Administrator UI → Analytics & Reporting (User Management flows)
- Customer Homes → ROM → DSRIP AOM → Chai Pro

Figure A-6 shows the use case sequence diagram for admin users to view customer reports. Admin users are provided both a real-time "dashboard" view of customers as well as canned reports subject to authorization rules.

Figure A-6: Administrator View of Customer Reports



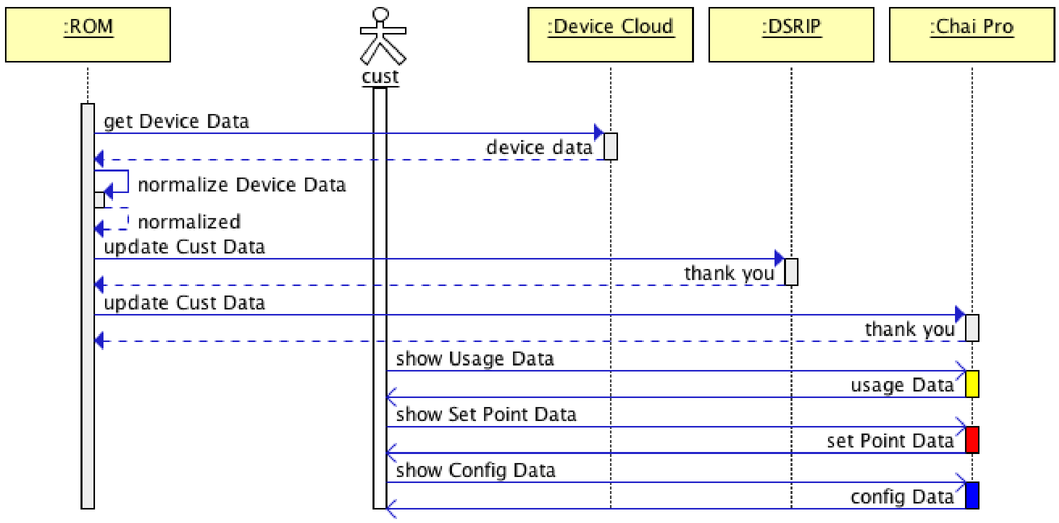
Source: EPRI

The pertinent aspect of this use case is the ability of the admin user to get authorized access to customer's dashboard info and their historical reports. If the user is not authorized to view the customer's information, they are redirected to an "Unauthorized Access" error page.

Use Case 2.1: Customer Views of Usage, Set Point and Configuration Data

Figure A-7 shows the use case for how a customer views their usage data (or set-point and configuration data).

Figure A-7: Customer Views of Usage, Set Point, and Configuration Data



Source: EPRI

User sign-up is handled via a specific Active Directory Admin access page which allows users (DSRIP program participants – customers, and Administrative Users) to create authenticated and authorized access to view their data.

Use Case 2.2: Customer signs up and registers with the Open Demand Side Resource Integration Platform

User sign-up is handled via a specific Active Directory Admin access page which allows users (DSRIP program participants – customers, and Administrative Users) to create authenticated and authorized access to view their data.

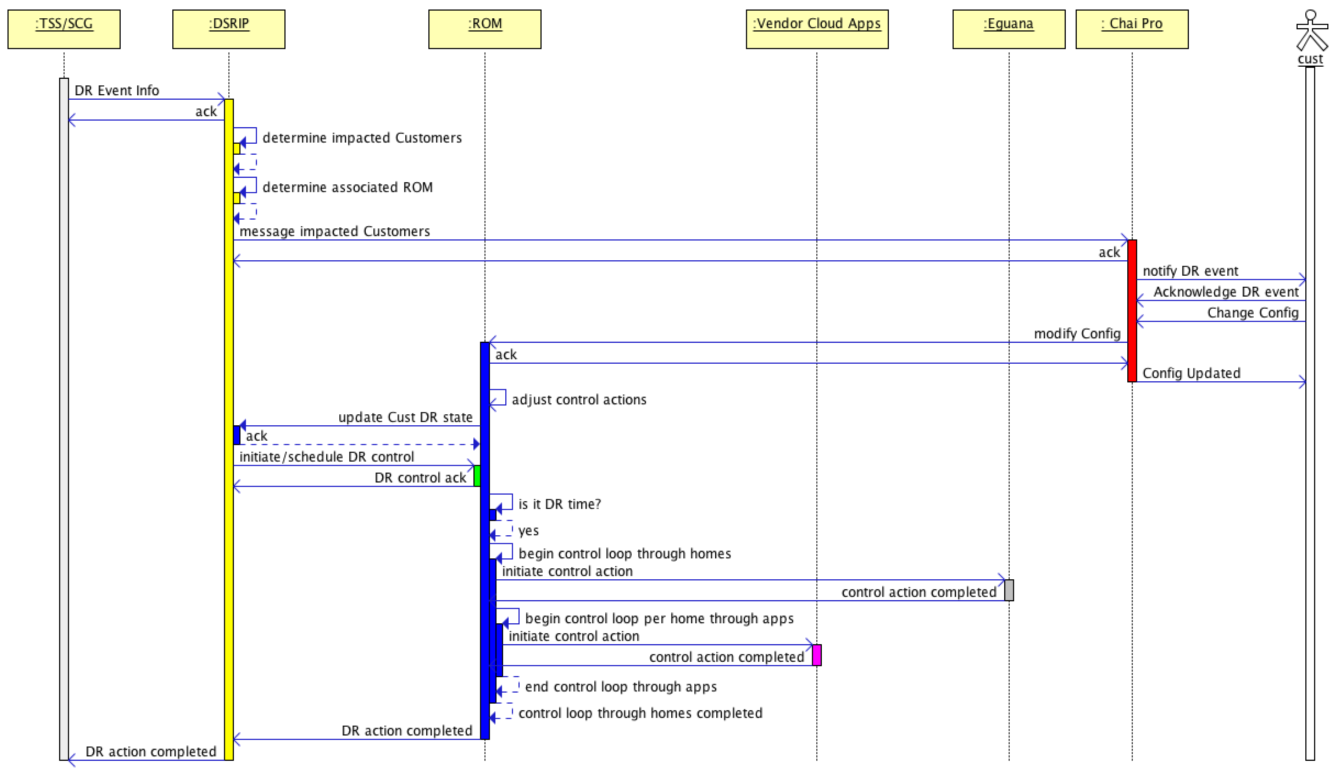
Use Case #3: Demand Response Scenario Flows

- EPRI TSS VTN → Utility Abstraction → Control Module → Aggregation & Orchestration → EPRI OVGIP + Energy360 + ROM; Data Aggregation Flow (for M&V analysis)

Use Case #3.1: Principal End-to-End DR Use Case without EV involved

Figure A-8 shows the principal end-to-end DR use case for DSRIP. While the customer messaging and customer configuration update are included in this use case, a more detailed treatment of these two use cases is done elsewhere. The pertinent aspect of this use case is that it does not involve EV/OVGIP. Also, ROM is responsible for determining when the DR/TOU/Rate-Change event happens and schedules control actions accordingly. Finally, while most control actions are directed towards vendor-specific cloud applications, for actions directed at the battery energy management system, the ROM must act at a per-home level. The DR action is complete after receiving a completion notice from all associated applications. If there is an error with any of the interfacing cloud applications, ROM will attempt to retry the action. Upon repeated failure, ROM reports the failure event to DSRIP.

Figure A-8: Demand Response Use Case Without Electric Vehicles

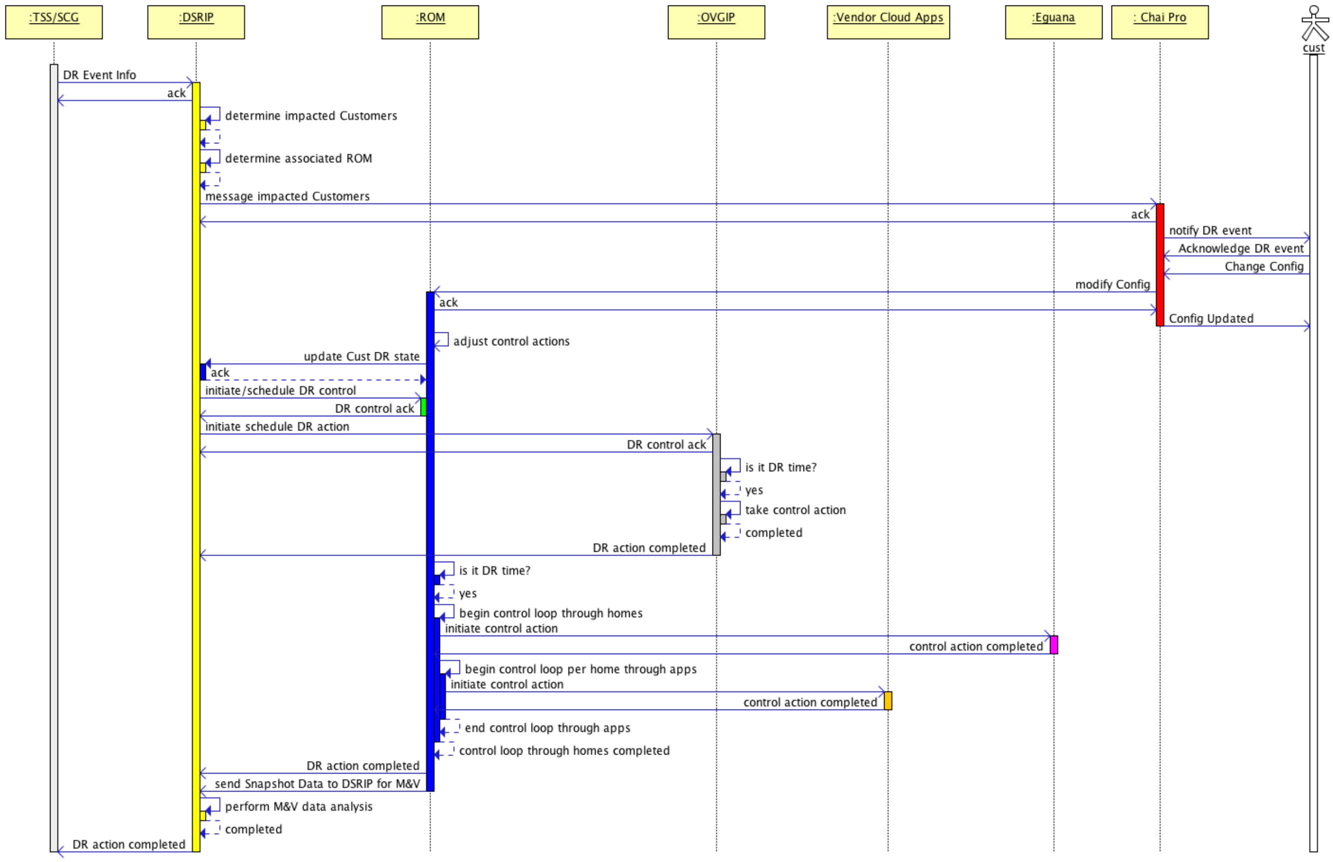


Source: EPRI

Use Case #3.2: Principal End-to-End DR Use Case with Electric Vehicles Involved

Figure A-9 shows the principal End-to-End DR use case but with EVs involved in the overall control action for a specific customer. The addition of control action initiated by DSRIP towards OVGIP is to execute EV related control actions. Note that electric vehicles (even ones that are being charged at a customer's home) are controlled through OVGIP as opposed to control through ROM. This is because ROM is not aware of the energy use by the EV. This constraint reduces the amount of flexibility available for EV charging DR control (e.g., do not charge EV during peak rate periods if EV is more than 80 percent charged).

Figure A-9: Demand Response Use Case with Electric Vehicles



Source: EPRI

Use Case #4: Rate Change Message Flows

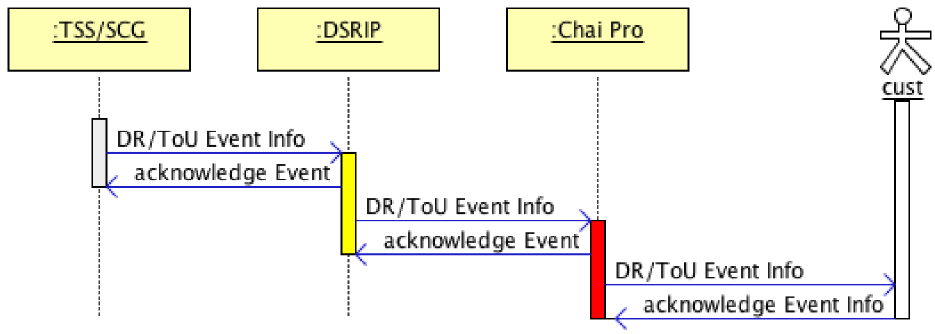
Messaging flows are used to inform the customer of impending DR events or impending TOU rate change events. The principal components involved in these flows are:

- Olivine SCG → Utility Abstraction → Control Module → Aggregation & Orchestration → Chai Pro
- EPRI TSS VTN → Utility Abstraction → Control Module → Aggregation & Orchestration → Chai Pro

Use Case #4.1: Customer receives a message regarding an upcoming DR/TOU/rate-change event

Figure A-10 shows the sequence diagram for the messaging use case.

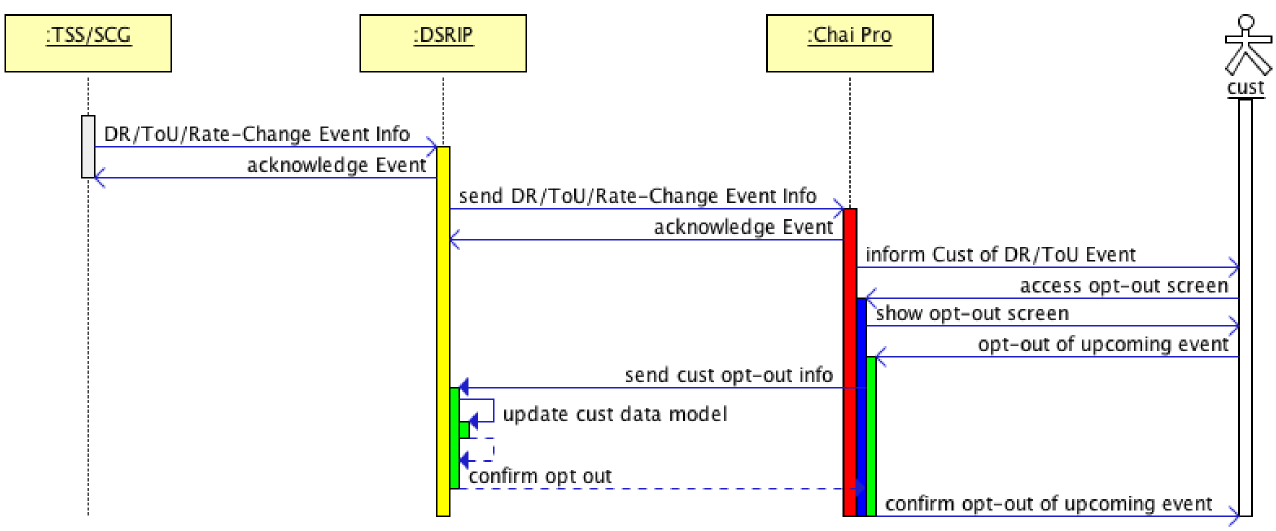
Figure A-10: Customer Receives Message Regarding Upcoming DR/TOU/Rate-Change Event



Source: EPRI

The most pertinent part of the messaging flow is the asynchronous nature of the communications between systems, such that the customer gets informed of the upcoming event with sufficient notice to be able to take any consequent action if necessary. Consequent actions to messaging could range from simply acknowledging the notification to changing their preferences or even opting out of the upcoming event. See Figure A-11.

Figure A-11: Customer Configures Their Preferences through User Interfaces (e.g., the Chai Pro)



Source: EPRI

Use Case #4.2: Customer opts out of DR control for an upcoming event

Figure A-11 shows the sequence diagram for the use case where a customer configures his/her preferences for how DR events are to be handled in conjunction with his/her comfort level.

Functional Requirements

Functional requirements are numbered using the following convention:

<SYSTEM>-<Subsystem Code>-#

where:

1. <SYSTEM> is either DSRIP or ROM depending upon which system's requirements are being specified.
2. <Subsystem Code> represents a mnemonic for the subsystem (within DSRIP) for which requirements are being specified. Table A-1 shows a table of subsystem mnemonics.
3. # represents the requirements number.

Table A-1: Subsystem Codes for DSRIP requirements specification

Subsystem Code	Subsystem
UM	User Management
AOM	Aggregation and Orchestration Module
UAM	Utility Abstraction Module
CM	Control Module
ARM	Analytics and Reporting Module
UI	User Interface

Source: EPRI

Requirements Language Clarification

Requirements are written to be clear enough to develop but also easy to develop test cases. In that sense, any requirement that has the word "shall" is mandatory. Optional requirements are identified as such using appropriate (and clear) language. Requirements that are conditionally dependent upon other requirements are identified as related to other requirements using appropriate (and clear) language. Requirements are also related to the use cases using the use case number identified by appropriate heading numbers, e.g., Use Case #1 identifies the use case.

User Management

Convention

Given that there are multiple "types" of users that participate in the DSRIP system, we use the term "User" to mean either an Administrative User who has login permissions to the DSRIP User Interface or a customer who is a participant in the DSRIP system and has access to his/her household information available via Chai Pro application on their mobile devices and online access through Chai Pro user credentials.

User Registration and Account Management

See Table A-2 for User Registration Requirements.

Table A-2: User Registration Requirements

Requirement Number	Requirements Text
DSRIP-UM-10	DSRIP shall provide a mechanism (webpage/specific Active Directory Admin accessible page) to allow program participants (customers) and select users from stakeholder organizations to create accounts for authenticated and authorized access to view DSRIP real-time and historical reports.

Source: EPRI

Customer Registration

Chai Pro[1] is a residential customer-facing application and thus it plays a central role in the residential customer registration process. Given that Chai Pro is already in use, the set of requirements for Chai Pro (identified via Chai Pro-Reg-# requirements numbers) needs to be slotted into an appropriate Chai Pro release. It is strictly outside the scope of the current requirements document to specify a release schedule for the Chai Pro application. See Table A-3.

Table A-3: Chai Pro Requirements for Customer Registration

Requirement Number	Requirements Text	Use case
Chai Pro-Reg-10	Chai Pro shall provide customers the ability to register for the DSRIP program.	2.2
Chai Pro-Reg-20	Chai Pro shall collect the following items of information as part of the DSRIP customer registration process: 1) Customer First, Last name. 2) Customer address 3) Customer email address 4) Utility serving the customer 5) Customer's consent to participate in the DSRIP program 6) Customer's signature consenting to participation.	2.2

Source: EPRI

[1] The Chai Pro was replaced during the project due to a combination of a change in business direction of Chai Energy as well as site provider requests to use other forms of mobile and/or voice applications (e.g., Amazon Echo) to not impede current product offerings. Chai Pro will be used to represent other user interfaces that were also used as part of residential demonstrations as functional requirements remain the same.

Customer Authentication and Authorization

See Table A-4.

Table A-4: Chai Pro Requirements for Customer Authentication and Authorization

Requirement Number	Requirements Text	Use case
Chai Pro-Reg-50	Chai Pro shall use its existing authentication mechanism and not require the customer to use a separate authentication mechanism for DSRIP.	2.2
Chai Pro-Reg-60	Chai Pro shall provide customers the ability to view only "their" household information.	2.1
Chai Pro- Reg-70	Chai Pro shall provide a customer (and the sub-accounts associated with the main customer account), access to the household that they have registered.	2.1

Source: EPRI

Aggregation and Orchestration Module

Aggregation of Residential and Commercial Customer data

See Table A-5.

Table A-5: DSRIP requirements for Aggregation of Residential and Commercial customer data

Requirement Number	Requirements Text	Use case	Related to
DSRIP-AOM-10	DSRIP shall provide an API for the Residential Orchestration Module to post data periodically.	1	
DSRIP-AOM-20	DSRIP shall provide an API for OVGIP to post electric vehicle energy data periodically.		
DSRIP-AOM-30	DSRIP shall provide an API for Energy360 to post electric vehicle energy data periodically.		
DSRIP-AOM-40	DSRIP shall provide an API for Chai Pro to post customer registration data. The interface shall provide for the following distinct classes of data: 1) Customer Registration Information 2) Customer Signature (as part of the registration process) as an image file.	2.1	
DSRIP-AOM-80	DSRIP AOM shall receive the ROM instance identifier from the ROM Factory as a response to the request to ROM Factory to create a ROM instance.	2.2	

Requirement Number	Requirements Text	Use case	Related to
DSRIP-AOM-90	DSRIP AOM shall provide DSRIP ARM with the ROM instance identifier associated with the newly registered customer's site.	2.1	DSRIP-AOM-80
DSRIP-AOM-110	DSRIP AOM shall provide an API for ROM to receive control actions as a result of DR/TOU/rate-change events determined by DSRIP CM.	3.1, 3.2	
DSRIP-AOM-120	DSRIP AOM shall implement an openADR2.0B compatible VEN instance for receiving DR event and TOU rate change information from TSS and SCG.	3.1, 3.2	
DSRIP-AOM-130	DSRIP AOM shall provide the DSRIP UAM with the DR event and TOU rate change information received from TSS/SCG to initiate the end-to-end DR flow.	3.1, 3.2	
DSRIP-AOM-150	DSRIP AOM shall receive a list of impacted customers associated with a DR event along with the associated "action" information.	3.1, 3.2, 4	
DSRIP-AOM-160	DSRIP AOM shall notify Chai Pro of impending DR/TOU event upon receiving notification from DSRIP CM with a list of impacted customers with action set to "MESSAGE."	4.1	
DSRIP-AOM-170	DSRIP AOM shall receive an acknowledgment from Chai Pro upon requesting Chai Pro to notify impacted customers of the impending DR/TOU event.	4.1	
DSRIP-AOM-200	DSRIP AOM shall request DSRIP ARM to update the customer's DR participation state upon receiving customer preference configuration information from Chai Pro.	4.2	
DSRIP-AOM-210	DSRIP AOM shall receive success/failure from DSRIP ARM in response to the request to update the customer's DR participation state.	4.2	
DSRIP-AOM-220	DSRIP AOM shall respond to ROM with the success/ failure to update customer's DR participation state.	4.2	

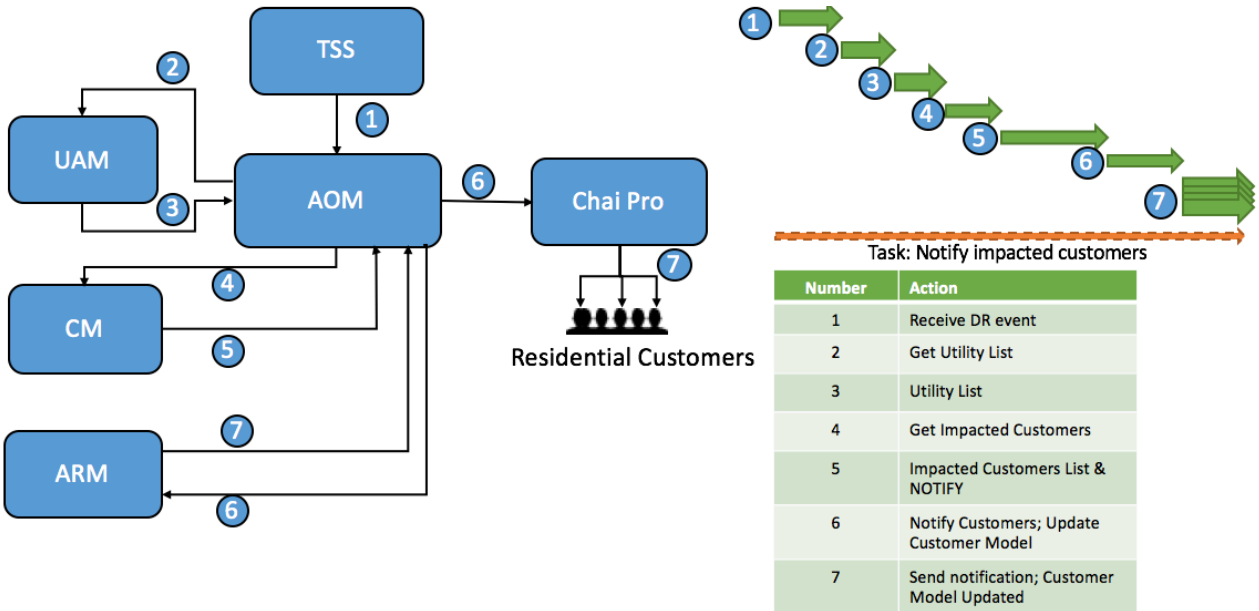
Source: EPRI

Orchestration Performance by the Demand Side Resource Integration Platform

Orchestration, within the context of the DSRIP, is defined as the function that organizes a set of high-level actions into a coherent sequence of one or more low-level actions to obtain the information necessary for effecting the high-level actions. For example, Figure A-12 shows how AOM orchestrates the high-level action of "notifying impacted customers of an impending DR event". The trigger for this event could be the receipt of a DR event notification from TSS.

Note that the Residential Orchestration Module (ROM) also performs its own set of orchestration tasks but that is done at a different level of granularity compared to the DSRIP.

Figure A-12: Orchestration for Effecting "Notify Customers of Impeding DR Event" High-Level Action



Source: EPRI

Utility Abstraction Module

The DSRIP Utility Abstraction Module (UAM) is responsible for interpreting DR/TOU/rate-change signals from Utility systems (TSS and SCG) and initiating the necessary flows that will ensure that the signals result in appropriate consequent actions. See Table A-6.

Table A-6: Open Demand Side Resource Integration Platform Requirements for Utility Abstraction Module

Requirement Number	Requirements Text	Use case
DSRIP-UAM-10	DSRIP UAM shall be capable of interpreting OpenADR2.0B compatible rate change signals	1
DSRIP-UAM-20	DSRIP UAM shall identify the list of utilities when DSRIP AOM requests UAM when AOM receives a DR or rate change signal.	3.1, 3.2

Source: EPRI

Control Module

The DSRIP Control Module provides information that (a) helps delegated systems determine appropriate control action that needs to be taken (b) impacted list of sites, vehicles, and commercial entities so that appropriate control actions may be taken in response to a DR or

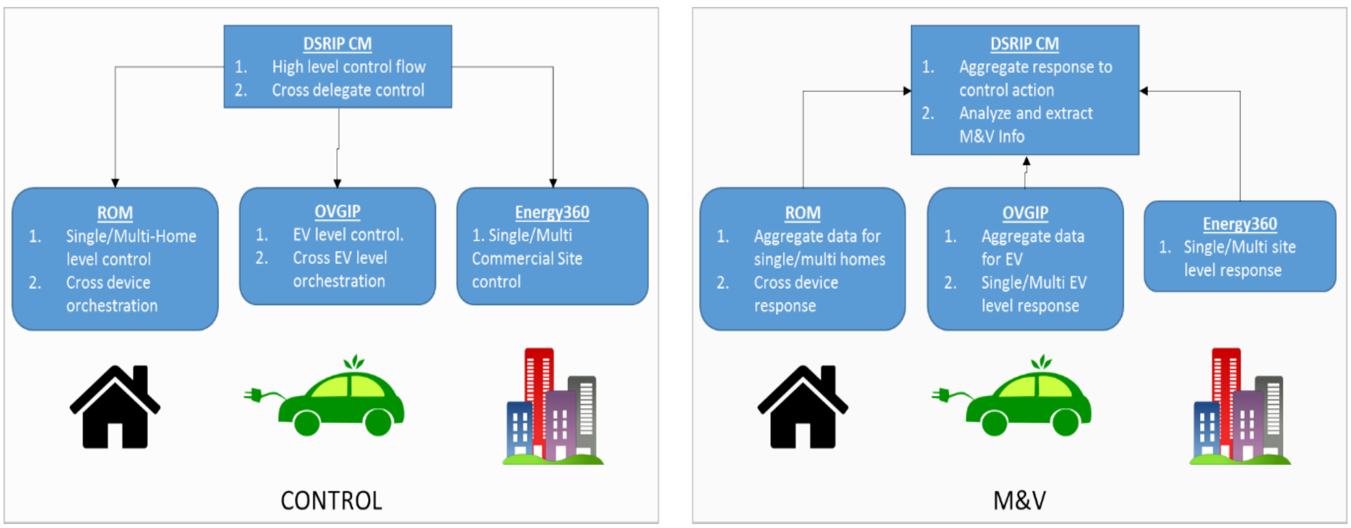
Rate change event. The control module determines the high-level flow order and the impacted list of users. An example of a high-level flow could be:

1. Determine a list of impacted sites, vehicles and commercial sites based on the utilities involved in the DR / Rate change event.
2. Notify impacted users of upcoming DR/Rate change event.
3. Schedule control action based on the impact list with delegated systems.
4. Determine overall response to scheduled control actions based on individual responses from delegated systems.

Control Granularity and Scalability

Control actions in the DSRIP are driven using a federated approach to ensure that the control granularity can sustain a scalable increase in customer and data volume and variability in end-user devices. The federated control and M&V architecture are shown in Figure A-13.

Figure A-13: Federated Control and Measurement and Verification Architecture



Source: EPRI

Scalability is achieved by:

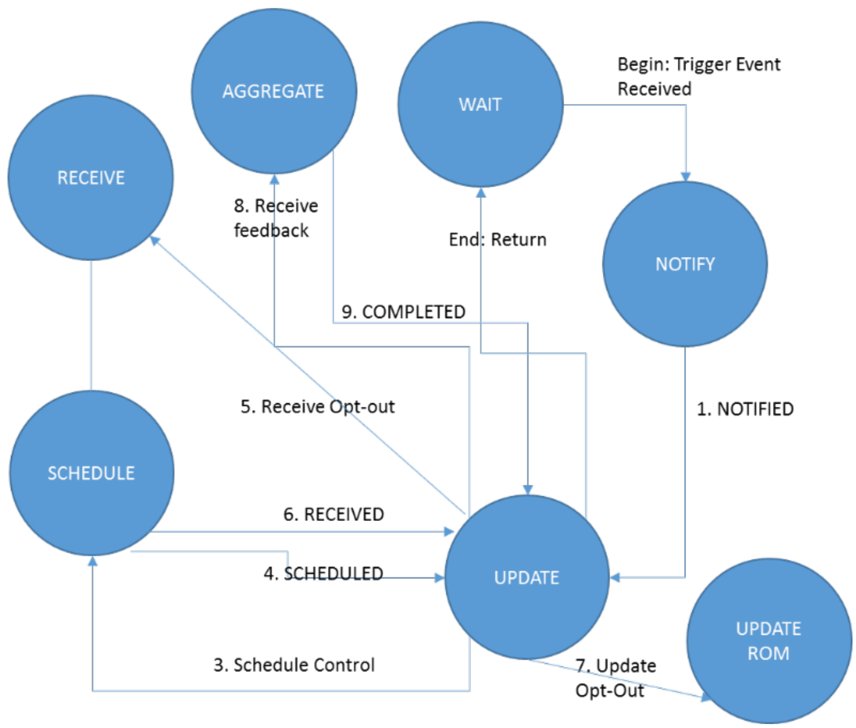
1. Dividing responsibility between DSRIP CM and delegated systems for implementing control actions at various hierarchical levels.
    a. DSRIP CM – utility level abstraction of control actions, i.e., high-level control flow.
    b. ROM – single/multiple home level control actions in conjunction with user preferences, e.g., change set-point to +/- 3° F to allow for reduced energy use.
    c. OVGIP – single/multiple electric vehicle level control actions in conjunction with user preferences, e.g., if the car is more than 70 percent charged, do not charge the car during high-rate periods.

    d. Energy360 – single/multiple commercial site level control actions, i.e., similar to ROM except for commercial sites.
2. Using DSRIP as the database of record and allowing for analytical applications to be driven from DSRIP at various levels of granularity.
    a. ROM – response to scheduled control actions, aggregation, and normalization of single/multiple home-level data to DSRIP for M&V.
    b. OVGIP – response to scheduled control actions, aggregation, and normalization of Electric Vehicle data to DSRIP.
    c. Energy360 – response to scheduled control actions, aggregation, and normalization of data from commercial sites to DSRIP.
    d. DSRIP – aggregation of response to control actions, analysis, and distilling information from aggregated data for M&V.
3. Visualizing the impact of control actions on various DR events at different levels of granularity.
    a. DSRIP – utility view into pre- and post-event energy use at customer and higher aggregation levels.
    b. Chai Pro – customer view of a single/multiple home pre- and post-event energy use.
    c. Energy360 – customer view of single/multiple commercial site pre and post-event energy use.

See Table A-7.

Table A-7: DSRIP Requirements for Control Module

Requirement Number	Requirements Text	Use case
DSRIP-CM-10	DSRIP CM shall determine the list of "impacted" sites involved in a DR/Rate-change event.	3.1, 3.2, 4.1
DSRIP-CM-40	DSRIP CM shall determine the list of EVs associated with households in an event.	3.2
DSRIP-CM-50	DSRIP CM shall determine the list of "impacted" commercial sites involved in an event.	
DSRIP-CM-50	DSRIP CM shall determine if a commercial site is impacted by a DR event using the opt-in/opt-out state for the commercial site in DSRIP.	
DSRIP-CM-70	DSRIP CM shall provide a default set of high-level actions in response to an event. The default set of actions include: 1. NOTIFY impacted customers of an upcoming event. 2. UPDATE impacted customer model as "notified." 3. SCHEDULE control actions for customers. 4. UPDATE customer model with event scheduling information.	3.1, 3.2

<table>
<tr><th>Requirement Number</th><th>Requirements Text</th><th>Use case</th></tr>
<tr><td></td><td>
5. RECEIVE opt-out (if any) for customers who have opted out from Chai Pro
6. UPDATE customer model with opt-out information.
7. UPDATE ROM for customers that have opted out of the event.
8. AGGREGATE control responses from delegated systems to determine the overall response status.
9. UPDATE customer model with event completion information.


</td><td></td></tr>
<tr><td>DSRIP-CM-80</td><td>DSRIP shall determine the overall response to an event by aggregating responses from delegated systems (ROM, OVGIP and Energy360) depending upon which of the delegated systems were involved in the event's control actions. A simple aggregation logic would be implemented as default:
1. If responses from all delegated systems are COMPLETE, then the overall DSRIP state is COMPLETE.
2. If the response from at least one of the delegated systems is IN-PROGRESS, then the overall DSRIP state is IN-PROGRESS.
3. If the response from at least one of the delegated systems is ERROR, then the overall DSRIP state is INCOMPLETE.</td><td>3.1, 3.2</td></tr>
</table>

Source: EPRI

Reactive Control

Reactive control refers to the paradigm where DSRIP and the delegate systems take control actions in response to an external DR event, e.g., upon receiving a dynamic DR event from

TSS. Reactive control often requires near real-time action and near real-time collection and analysis of feedback and M&V data.

Proactive Control

Proactive control refers to the paradigm where DSRIP and delegate systems take control action proactively to an upcoming event, e.g., pre-cooling in HVAC systems before the beginning of TOU rate peak. Proactive control requires the implementation of scheduled control actions and longer-term collection and analysis of feedback and M&V data.

Analytics and Reporting Module

DSRIP Analytics and Reporting Module (ARM) provides a set of functions that support various analytical purposes within the DSRIP platform. The analytical applications in DSRIP platform are principally of 3 kinds:

1. Analytics in support of M&V for control actions: Functions that support M&V for control actions taken by the DSRIP platform including the analysis of received data from delegated systems to determine the effects of a DR event.
2. Analytics in support of real-time reporting: Functions that support the administrative user's real-time customer dashboard.
3. Analytics in support of reports: Functions that support the administrative user's historical customer reports.
4. Analytics in support of ad-hoc queries: Functions that support the transformation of data amenable for ad-hoc data extraction.

Analytics in Support of M&V for Control Actions

See Table A-8.

Table A-8: Open Demand Side Resource Integration Platform Requirements for Supporting M&V for Control Actions

Requirement Number	Requirements Text	Use case	Related to
DSRIP-ARM-10	DSRIP ARM shall provide a variety of analytical functions that support M&V of control actions.	3.1, 3.2	
DSRIP-ARM-20	DSRIP ARM shall provide functions that help visualize energy use on a per-site basis including actuals v. projected use corresponding to specific Rate-Change events.	3.1, 3.2	
DSRIP-ARM-30	DSRIP ARM shall use a given site's historical use medians to estimate projected use for specific events conditioned by weekday/weekend differences.	3.1, 3.2	DSRIP-ARM-20

Requirement Number	Requirements Text	Use case	Related to
DSRIP-ARM-40	DSRIP ARM shall distinctively indicate start/stop boundaries of DR events in time-series plots used for visualizing energy use.	3.1, 3.2	
DSRIP-ARM-50	DSRIP ARM shall provide functions that help administrative users visualize the comparison between various entities to help elucidate differences. Note: this is an umbrella requirement detailed further in the related requirement.	2.1	
DSRIP-ARM-60	DSRIP ARM shall support functions that can compare the following: 1. Two or more sites for a specific DR event. 2. Two or more collections of sites for a specific DR event with collections defined along device lines (e.g., EV ownership, battery ownership, etc.) 3. Two or more events for a specific site. 4. Two or more events across a grouping of sites (e.g., EV households)	2.1	DSRIP-ARM-50

Source: EPRI

Analytics in Support of Real-Time Reporting

See Table A-9.

Table A-9: Open Demand Side Resource Integration Platform Requirements for Real-time Reporting

Requirement Number	Requirements Text	Use case	Related to
DSRIP-ARM-70	DSRIP ARM shall provide a variety of analytical functions that support real-time reporting at the site level.	2.1	
DSRIP-ARM-80	DSRIP ARM shall provide in “real-time” a view of a site: 1. Current energy use 2. Today’s total use to date 3. Current loads (HVAC, HPWH, Inverter, Appliances) 4. Last event energy use actual v. projected 5. Next event schedule and participation state.	2.1	DSRIP-ARM-70

Source: EPRI

Analytics in Support of Historical Reporting

See Table A-10.

Table A-10: DSRIP ARM Requirements for Historical Reporting

Requirement Number	Requirements Text	Use case
DSRIP-ARM-90	DSRIP ARM shall provide a variety of analytical functions that support historical reporting at the site level.	2.1
DSRIP-ARM-100	DSRIP ARM shall optionally provide the following historical reporting functions on a per-site basis: 1. Trend of total energy use by day 2. Trend of total energy use by DR event that the site has participated in. 3. Trend of total energy use by DR event that the household has opted out.	2.1

Source: EPRI

Analytics in support of Ad-Hoc Data Extraction

See Table A-11.

Table A-11: Open Demand Side Resource Integration Platform Requirements for Ad-Hoc Data Extraction

Requirement Number	Requirements Text
DSRIP-ARM-110	DSRIP ARM shall provide a variety of functions that support the archiving of data to an "analytics" database so that ad-hoc data extraction queries may be executed to acquire data. Note: This data could be exposed via an authenticated API access mechanism.

Source: EPRI

User Interface Requirements

DSRIP User Interface serves the purpose of providing a mechanism for program participants (utility administrative users) to be able to get authorized access to view energy use information. The requirements laid out in this that primarily concern #0 are split between DSRIP for administrative users (see Table A-12) and Chai Pro for customers (see Table A-13).

Table A-12: Open Demand Side Resource Integration Platform User Interface Requirements

Requirement Number	Requirements Text	Use case
DSRIP- UI-10	DSRIP UI shall provide logged-in administrative users with a DSRIP dashboard which includes the following information: 1. Energy use trends across all the customers served by the utility participating in the DSRIP program. 2. Visually distinctive indicators of DR/rate-change events that have taken place. 3. Scheduled DR/rate change events for the utility.	2.1
DSRIP-UI-20	DSRIP UI shall provide logged-in administrative users with a customer dashboard. The customer list in the dashboard shall be restricted to the specific utility of the administrative user. Contents of the dashboard are driven by the analytics detailed in DSRIP-ARM-80.	2.1
DSRIP-UI-30	DSRIP UI shall provide logged-in administrative users access to customer historical reports. The customer list in the dashboard shall be restricted to the specific utility of the administrative user. Contents of the historical reports are driven by the analytics detailed in DSRIP-ARM-100.	2.1

Source: EPRI

Table A-13: Chai Pro User Interface Requirements

Requirement Number	Requirements Text	Use case
Chai Pro-UI-10	Chai Pro UI shall be enhanced to show the customer a dashboard view of all of the device-level energy use data.	2.2
Chai Pro-UI-20	Chai Pro UI shall be enhanced to show the customer a view of all of the setpoint data about the devices that are monitored.	2.2
Chai Pro-UI-30	Chai Pro UI shall be enhanced to show the customer a dashboard view of DR event data using modeled vs. actual energy use.	2.2

Source: EPRI

Interface Requirements of the Open Demand Side Resource Integration Platform

OpenDSRIP has several external interfaces which provide and/or respond to data and control signals for DR/rate-change signals. The interface requirements detailed here are strictly restricted to interface transactions and minimal interface processing (e.g., interface schema validation). Functional requirements provide what functions are performed on the data that is sent or received over these interfaces. As a rule, all values enclosed in double quotes ("xyz") or single quotes (‘xys’) are to be considered literals. The interface area and the associated mnemonic are shown in Table A-14.

Table A-14: Open Demand Side Resource Integration Platform Interface Requirements Area

Function Name	Mnemonic
Generic	GEN
Transactive Signal Server	TSS
Olivine SCG	SCG
Energy360	E360
OVGIP	OVGIP
Ad-hoc Data Access	ADA
Residential Orchestration Module	ROM
Chai Pro	CPI

Source: EPRI

Generic Interface Requirements

See Table A-15.

Table A-15: Open Demand Side Resource Integration Platform Generic Interface Requirements

Requirement Number	Requirements Text
DSRIP-GEN-10	All applications that interface with DSRIP shall register with DSRIP to establish authentication and authorization credentials. Registration with DSRIP is done using OAuth2 framework. A precursor to registration with DSRIP is for the connecting application to register with Azure Active Directory and obtain an Azure AD Client ID and Azure AD Client Key (also called Client Secret). After obtaining the client id and client secret, the application is required to obtain an access token using an HTTP Post request to the following website: http://login.microsoftonline.com/<dsrip_tenant_id>/oauth2/token Post Parameters: grant_type: required, must be set to ‘client_credentials’ client_id: required, set to Azure AD Client ID client_secret: required, set to Azure AD Client Key resource: required, Azure App ID URI of DSRIP Note: As part of formal interface connectivity and testing, DSRIP has multiple “tenant ID” and “resource URI”. The full set of dsrip_tenant_id and resource fields are provided at the time of interface connectivity testing.

Requirement Number	Requirements Text
	If this POST request results in a 200 (OK) response, then it will return a JSON Web Token (jwt) access token. Use the jwt access token to access a set of services on DSRIP with the following endpoint: with the <opendsrip_web_api_domain> available to applications at the time of interface connectivity testing. The Header of the request to the web API end-point has to include: Authorization: Bearer <jwt access token>
DSRIP-GEN-20	DSRIP shall support HTTP as a transport layer (as opposed to XMPP) for all openADR2.0B messages with external VTN and VEN entities.
DSRIP-GEN-30	DSRIP shall support a PUSH interaction pattern for all openADR2.0B messages.
DSRIP-GEN-40	DSRIP openADR2.0B EiEvent messages sent to VEN entities will have the VEN Response Required parameter set to "always".

Source: EPRI

Transactive Signal Server Interface

See Table A-16.

Table A-16: Open Demand Side Resource Integration Platform Transactive Signal Server Interface Requirements

Requirement Number	Requirements Text
DSRIP-TSS-10	DSRIP shall implement a VEN for receiving openADR2.0B DR signals from TSS.
DSRIP-TSS-20	DSRIP shall receive an EiEvent Service from TSS with an appropriate oadrDistributeEvent message. DSRIP shall respond with a HTTP 200 upon receiving the oadrDistributeEvent message.
DSRIP-TSS-30	DSRIP shall be capable of receiving multiple oadrEvent elements in the oadrDistributeEvent message.
DSRIP-TSS-40	DSRIP shall respond to TSS with an oadrCreatedEvent message as a response to the oadrDistributeEvent message received from TSS. oadrCreatedEvent will capture the appropriate requestID received from TSS in the oadrDistributeEvent message.
DSRIP-TSS-50	DSRIP shall only accept the following types of signals from TSS: signalName = ELETRICITY_PRICE; signalType = {price, priceRelative, priceMultiplier}

Requirement Number	Requirements Text
	For TOU events: there are multiple equal-sized intervals, all of which have the same signalType, and each interval is specified with rate attributes. An example is shown below: ▪ Signal Type: price ▪ Units: USD per Kwh ▪ Number of intervals: equal TOU Tier changes in 24 hours (2 - 6) ▪ Interval Duration(s): TOU tier active time frame (i.e. 6 hours) ▪ Typical Interval Value(s): $0.10 to $1.00 (current tier rate) ▪ Signal Target: None For Peak Pricing events: there may be multiple interval values, all of which have the same signalType, and each interval is specified with rate attributes. An example is shown below: o Signal Name: ELECTRICITY_PRICE ▪ Signal Type: price ▪ Units: USD per Kwh ▪ Number of intervals 3 ▪ Interval Duration(s): 1 hour, 4 hours, 1 hour ▪ Typical Interval Value(s): $0.50, $0.75, $0.50 (for each interval respectively) ▪ Signal Target: None

Source: EPRI

Residential Orchestration Module Interface

ROM interface requirements are laid out in two parts – (a) Data Acquisition (See Table A-17) and (b) Control Signaling and Response (See Table A-18).

Residential Orchestration Module Data Acquisition Interface

See Table A-17.

Table A-17: Residential Orchestration Module Data Acquisition Interface Requirements

Requirement Number	Requirements Text	Use case	Related to
DSRIP-ROM-10	ROM shall implement a data "posting" API with DSRIP such as data that is acquired from various interfacing cloud applications and collocated EMS can be posted to DSRIP periodically.	1	
DSRIP-ROM-20	DSRIP shall publish a generic RESTful API that can consume a JSON data digest posted from ROM.	1	

DSRIP-ROM-30	ROM shall post Sitesage data to DSRIP using the following generic format:
	{
	"household_id": string,
	"data": [{
	"timestamp": string,
		1	DSRIP-ROM-20

Requirement Number	Requirements Text	Use case	Related to
	"channel_id": string, "channel_name": string, "value": string }, {… }] }		

DSRIP-ROM-40	ROM shall post HVAC data to DSRIP using the following generic format:
	{
	"household_id": string,
	"thermostat_id": string,
	"data": [{
	"timestamp": string,
	"hvacmode": string,
	"zonehvacmode": string,
	"zonecalendarevent": string,
	"zonecooltemp": string,
	"zoneheattemp": string,
	"zoneavetemp": string,
	"zonehumidity": string,
	"outdoortemp": string,
	"wind": string,
	"auxheat1": string,
	"auxheat2": string,
	"auxheat3": string,
	"compcool1": string,
	"compcool2": string,
	"compheat1": string,
	"compheat2": string,
	"fan": string,
	"dmoffset": string
	},
	{…
	}
	]
	}
		1	DSRIP-ROM-20

DSRIP-ROM-50	ROM shall post HPWH data using the following generic format:
	{
	"household_id": string,
	"device_id": string,
	"data": [{
		1	DSRIP-ROM-20

Requirement Number	Requirements Text	Use case	Related to

	"timestamp": string,
	"power": string,
	"sensor_data": [{
	"temperature": string
	},{…
	}
	]
	"state": string,
	"commodities": [{
	"code": set to one of (0,6,7)
	"name": set to one of (Electricity Consumed, Total Storage Capacity, Present Energy Storage Capacity),
	"units": set to W & W-hr,
	"estimated": string,
	"instantaneous": string,
	"cumulative": string
	},{…
	}
	],
	"setpoint": {
	"type": string,
	"data": [{
	"value": string
	},{…
	}
	],
	"units": set to one of (F, C),
	},
	"temperature": {
	"data": string,
	"units": set to one of (F, C)
	"device": string
	},
	"thermostat_mode": string,
	"fan_mode": string
	},
	{…
	}
	]
	}		

Requirement Number	Requirements Text	Use case	Related to

DSRIP-ROM-60	ROM shall post appliance (LG) data to DSRIP using the following generic format:
	{
	“household_id”: string,
	“device_id”: string,
	“data”: [{
	“timestamp”: string,
	“fridgeTemp”: string,
	“freezerTemp”: string,
	“power”: string,
	“count”: string
	},
	{…
	}
	]
	}
		1	DSRIP-ROM-20

DSRIP-ROM-70	ROM shall post Solar Inverter data to DSRIP using the following generic format:
	{
	“household_id”: string,
	“site_id”: string,
	“data”: [{
	“timestamp”: string,
	“energy”: {
	“value”: string,
	“meters”: {
	“consumption”: string,
	“purchased”: string,
	“production”: string,
	“selfconsumption”: string,
	“feedin”: string
	}
	},
	“power”: {
	“value”: string,
	“meters”: {
	“consumption”: string,
	“purchased”: string,
	“production”: string,
	“selfconsumption”: string,
	“feedin”: string
	}
	},
		1	DSRIP-ROM-20

Requirement Number	Requirements Text	Use case	Related to

	“storage”: {
	“batterycount”: string,
	“batteries”:[{
	“power”: string,
	“batterystate”: string,
	“lifetimeenergydischarged”: string,
	“stateofcharge”: string
	},{…
	}
	}
	}
	]
	}		

Source: EPRI

Residential Orchestration Module Control Signaling and Response Interface

ROM control signaling and response will follow the openADR2.0B schema with a restricted set of messages to support DR control signaling. See Table A-18.

Table A-18: Open Demand Side Resource Integration Platform Control Signaling and Response Interface with the Residential Orchestration Module

Requirement Number	Requirements Text	Use case
DSRIP-ROM-80	ROM shall implement a RESTful end-point for receiving event information from DSRIP.	3.1, 3.2
DSRIP-ROM-90	ROM shall receive an event service that emulates the EiEvent Service with the appropriate oadrDistributeEvent message. ROM shall respond with an ack upon receiving the event message.	3.1, 3.2
DSRIP-ROM-100	ROM shall respond to DSRIP with a response to DSRIP. The response will capture the appropriate requestID received from TSS (sent via the DSRIP request message) in the oadrDistributeEvent message to be able to correlate to the main TSS event.	3.1, 3.2
DSRIP-ROM-110	ROM shall only accept the following types of signals from DSRIP: signalName = “ELECTRICITY_PRICE”; signalType = {price, priceRelative, priceMultiplier} For rate-change/TOU events: there are multiple equal-sized intervals, all of which have the same signalType, and each	3.1, 3.2

Requirement Number	Requirements Text	Use case

	interval is specified with rate attributes. An example is shown below:
	▪ Signal Type: price
	▪ Units: USD per Kwh
	▪ Number of intervals: equal TOU Tier changes in 24 hours (2 - 6)
	▪ Interval Duration(s): TOU tier active time frame (i.e. 6 hours)
	▪ Typical Interval Value(s): $0.10 to $1.00 (current tier rate)
	▪ Signal Target: None
	For Peak Pricing events: there may be multiple interval values, all of which have the same signalType, and each interval is specified with rate attributes. An example is shown below:
	○ Signal Name: ELECTRICITY_PRICE
	    ▪ Signal Type: price
	    ▪ Units: USD per Kwh
	    ▪ Number of intervals 3
	    ▪ Interval Duration(s): 1 hour, 4 hours, 1 hour
	    ▪ Typical Interval Value(s): $0.50, $0.75, $0.50 (for each interval respectively)
	    ▪ Signal Target: None	

Source: EPRI

Chai Pro Interface

See Table A-19.

Table A-19: Chai Pro Open Demand Side Resource Integration Platform Interface Requirements

Requirement Number	Requirements Text	Use case

DSRIP-CPI-10	DSRIP shall publish an API for Chai Pro to post customer registration information. The post parameters are as follows:
	{
	  "customer_id": string,
	  "timestamp": string,
	  "customer_consent": string,
	  "customer_consent_remarks": string
	}
	Additionally, Chai Pro shall include the customer signature image as a file upload.
		2.2

DSRIP-CPI-20	DSRIP shall send Chai Pro messages corresponding to information about upcoming Rate Change events to be disseminated to the customers. The post parameters are as follows:
	{
	  "post_unique_id": string,
	  "deploy_datetime": string,	

Requirement Number	Requirements Text	Use case

	"event_start_datetime": string,
	"event_end_datetime": string,
	"incentive_amount": string,
	"customer_ids": [{
	"customer_id": string,
	{…
	}
	]
	"messages": [{
	"message_id": string,
	"message_platform": string,
	"send_time": string,
	"message_content": string
	},
	{…
	}
	]
	}	

DSRIP-CPI-30	DSRIP shall publish an API for Chai Pro to send customer opt-out information for upcoming events:
	{
	"customer_id": string,
	"event_id": string,
	"opt_out_state": one of (1,0)
	}
	where "opt_out_state" is 1 if the customer opts out. Default is 0.
	Note: opt-out state of 0 is not necessary to send especially because the opt-out state is signaled on a per "event" basis.	

DSRIP-CPI-35	DSRIP shall send data to Chai via HTTP POST and will receive a HTTP 200 OK in response.	1
DSRIP-CPI-40	DSRIP shall post all timestamps in Epoch Time (seconds since Jan 1, 1970 UTC).	1
DSRIP-CPI-50	DSRIP shall post all data in SI units.	1
DSRIP-CPI-60	DSRIP shall not post more than 1 MB of data in each transaction.	1
DSRIP-CPI-70	DSRIP shall send data to the following URL: https://chai-digest.chaienergy.net	1

<table>
<tr><th>Requirement Number</th><th>Requirements Text</th><th>Use case</th></tr>
<tr><td>DSRIP-CPI-80</td><td>
The data to be posted needs to follow a specific template:
<table>
<tr><th>Field Name</th><th>Optional</th><th>Type</th><th>Description</th><th>Example</th></tr>
<tr><td>api_key</td><td>False</td><td>string</td><td>An API Key provided by Chai to identify supplier's credentials</td><td></td></tr>
<tr><td>supplier_name</td><td>False</td><td>string</td><td>The name of the supplier – used in conjunction with the api_key to validate requests</td><td></td></tr>
<tr><td>uid</td><td>False</td><td>string</td><td>Unique identifier representing the device's data. Note only 1 device worth of data can be sent at a given time</td><td></td></tr>
<tr><td>timestamp</td><td>False</td><td>timestamp</td><td>Current time as known by sender</td><td></td></tr>
<tr><td>data</td><td>False</td><td>list</td><td>Holds a list of DataCollection that ultimately hold the data to be saved. See below: DataCollections</td><td></td></tr>
<tr><td>version</td><td>False</td><td>string</td><td>the API version. currently the only value is 1.0</td><td>1.0</td></tr>
</table>
DataCollection structure:
<table>
<tr><th>Field Name</th><th>Optional</th><th>Type</th><th>Description</th></tr>
<tr><td>type</td><td>False</td><td>String</td><td>The type of data being sent. For instance if the data is related to current , then type is current. Note that the server will only accept pre-determined types. Unknown types will be discarded. Types are identified in the table below.</td></tr>
<tr><td>headers</td><td>True</td><td>List of Strings</td><td>If additional header columns are necessary, primarily used for "misc" types when the columns are ambiguous, or to alleviate confusion for other columns.</td></tr>
<tr><td>uid</td><td>True</td><td>String</td><td>If not included, we assume that the data is associated with the UID as given in the parent</td></tr>
<tr><td>data</td><td>False</td><td>List of datapoints</td><td>A list of datapoints, each one containing time stamp as well as data. Datapoints is a list of lists, See Datapoints below.</td></tr>
</table>
DataCollection type:
<table>
<tr><th>type</th><th>corresponding headers</th><th>description</th></tr>
<tr><td>power</td><td>[time, power]</td><td>used to transmit power time series</td></tr>
<tr><td>energy</td><td>[time, energy, duration]</td><td>used for energy data</td></tr>
<tr><td>voltage</td><td>[time, voltage]</td><td>used for voltage data</td></tr>
<tr><td>charge</td><td>[time, current]</td><td>used for charge percentage data</td></tr>
<tr><td>misc</td><td>[time, ..., ..., ...]</td><td>SPECIAL type:
When type "misc" is used, the header field MUST be specified. The header will be used to map the data to corresponding data types.
Mainly used when there is a lot of data being collected for the same timestamp.

EXAMPLE:
type: misc
header: [time, power, energy, energy_duration, voltage, current]
data: [
[<time>, <power value>, <energy value>, <energy_duration>, <voltage value>, <current value>],
[<time>, <power value>, <energy value>, <energy_duration>, <voltage value>, <current value>],
[<time>, <power value>, <energy value>, <energy_duration>, <voltage value>, <current value>],
]</td></tr>
<tr><td>log</td><td>[time, value]</td><td>SPECIAL type:
Log is not "processed" but will be stored. Can be used to send messages to server as needed. Status Join, etc.</td></tr>
</table>
Data Points:
<table>
<tr><th>type</th><th>datapoints</th><th>corresponding headers</th><th>Description</th></tr>
<tr><td>power</td><td>[<timestamp>, <power value>]</td><td>[time, power]</td><td>The power value is the instantanous usage as read by the device</td></tr>
<tr><td>energy</td><td>[<timestamp>, <energy value>, <duration>]</td><td>[time, energy, energy_duration]</td><td>Can be read as: at TIME to TIME + Duration, used this amount of ENERGY</td></tr>
<tr><td>voltage</td><td>[<timestamp>, <voltage value>]</td><td>[time, voltage]</td><td>The voltage at the given instance of time</td></tr>
<tr><td>charge</td><td>[<timestamp>, <charge value>]</td><td>[time, current]</td><td>The current at the given instance of time</td></tr>
</table>
</td><td></td></tr>
<tr><td>DSRIP -CPI-90</td><td>Chai Pro shall send customer Green Button data to DSRIP using the following format:
{
"customer_id": string,
"data": [{
"timestamp": string,
"data_type": string (e.g., "Green Button" or "AMI"),
"value": string
}</td><td></td></tr>
</table>

Requirement Number	Requirements Text	Use case
	… {}] }	

Source: EPRI

Main Lessons Learned

Main lessons learned from developing functional requirements of OpenDSRIP are detailed in Table A-20.

Table A-20: Lessons Learned Summary from Developing The Open Demand Side Resource Integration Platform Functional Requirements

Key Findings		Actions Taken
1.	OpenDSRIP needs to be split into two generic layers.	In the course of architecture development, to accommodate for wide variations in the availability and capabilities of behind-the-meter DER and to accommodate for a variety of implementation scenarios involving ISO, DSO, Community Choice Aggregators (CCA), and other utility entities, OpenDSRIP was split into two layers. The top layer referred to as DSRIP layer is comprised of invariant components that implement a set of grid-supporting functions. The bottom layer, referred to as Orchestration Layer, is comprised of DER management systems, DER aggregation systems, Home/Building Energy Management systems, Fleet charging control systems, and optionally custom-developed open-source orchestration modules (for example, ROM). This layer provides a pipeline for the acquisition of energy and operating data from behind-the-meter IoT and DER as well as supporting control functions.
2.	Customer Personally Identifiable Information (PII) needs to be handled effectively	Given that most of the data that is collected in DSRIP are from behind-the-meter IoT and DER, the potential for this data to contain customer PII is high. To prevent any exposure of PII, all customer identifiers are scrambled using Globally Unique Identifiers (GUID)/Universally Unique Identifiers (UUID) v4.
3.	Pricing Signals can potentially provide a customer-centric energy management stimulus.	Given the goal of OpenDSRIP was to test various types of rate regimes ranging from the day ahead TOU to Critical Peak Pricing (CPP) alongside including customer preferences in energy management decisions, pricing

Key Findings		Actions Taken
		signals provide a good starting point for energy management stimuli.
4.	Price Signals need to be supported by effective customer engagement mechanisms to effect energy-efficient behaviors.	To truly incorporate customer preferences which are likely to change over time and understanding that behind-the-meter IoT and DER have a primary contractual agreement with the customer (owner) for providing a stated purpose that may be energy-services/grid-service related, it is necessary to provide price signals in a way that is meaningful to the user. Consequently, approaches ranging from mobile apps to voice-assistant need to be incorporated to ascertain the effectiveness of the messaging mechanism.

Source: EPRI

CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix B: Functional Requirements of the Open Demand Side Resource Integration Platform's Residential Orchestration Module

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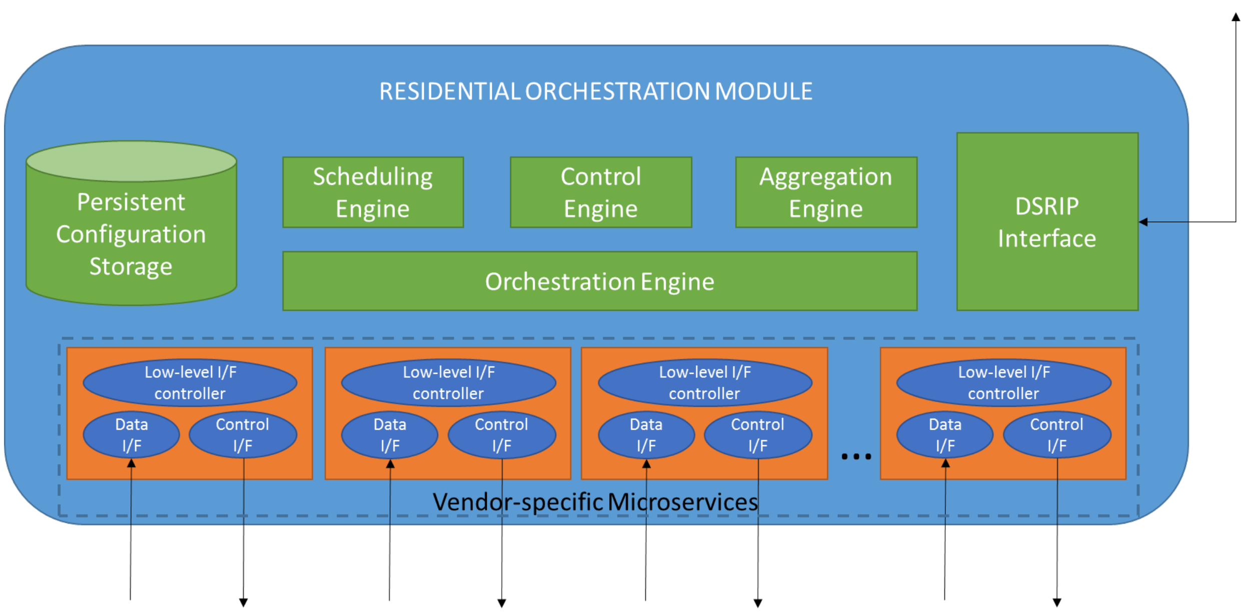
APPENDIX B:
Functional Requirements of the Open Demand Side Resource Integration Platform's Residential Orchestration Module

This appendix provides detail on the foundational aspects of a specific module of the OpenDSRIP platform, namely, the Residential Orchestration Module (ROM) that serves as a software gateway for collecting, collating, normalizing and providing data from connected devices. Additionally, the ROM also interprets rate change signals received from OpenDSRIP platform and translates these signals into an orchestrated control workflow to optimally reduce the overall energy consumption during high-rate events while ensuring that customer comfort preferences are respected.

Residential Orchestration Module Functional Architecture

The Residential Orchestration Module provides a scalable abstraction architecture for isolating low-level data acquisition and control tasks that are specific to a given customer's household and subject to customer preferences. The ROM by itself is developed as a containerized component with a collection of a few invariant functions and a few functions that are configuration driven. Figure B-1 shows the ROM functional architecture. Functions in green are the invariant components of the ROM whereas the configuration-specific functions are shown in orange. Each of the configuration-specific functions is developed as micro-services with

Figure B-1: Residential Orchestration Module Functional Architecture Showing Invariant (Green) and Configuration-Dependent (Orange) Functions



Source: EPRI

three internal functions supporting vendor-specific data and control interfaces and low-level interface controllers for implementing interface mediation rules. External interfaces are shown in thick dark lines crossing the boundary of the ROM.

The requirements for ROM are specified like DSRIP with each function identified by a mnemonic. For clarity, the mnemonic used for ROM is different from those used for DSRIP despite some similarities in the function names/descriptions. See Table B-1.

Table B-1: Residential Orchestration Module Functions and Associated Mnemonics

Function Name	Mnemonic
Persistent Configuration Storage	PCS
Scheduling Engine	SE
Orchestration Engine	OE
Aggregation Engine	AE
Control Engine	CE
DSRIP Interface	DI
Vendor Specific Microservices	VSM

Source: EPRI

DSRIP Interface

See Table B-2.

Table B-2: Residential Orchestration Module Requirements for Demand Side Resource Integration Platform Interface

Requirement Number	Requirements Text	Related to
ROM-DI-10	ROM shall provide DSRIP, the data aggregated from households(s) using a set of DSRIP provided APIs. The following sets of data are provided to DSRIP: 1. HVAC data 2. Water heater data 3. Solar Inverter data 4. Energy Storage data 5. Circuit level monitored data 6. Appliance level data	
ROM-DI-40	ROM shall accept event information from DSRIP and schedule control actions based on the type of event that is received, e.g., dynamic rate change event v. TOU rate change event. Note: TOU rate change events would require proactively scheduling control actions periodically as opposed to	

Requirement Number	Requirements Text	Related to
	dynamic rate change events which require control actions taken more reactively.	
ROM-DI-50	ROM shall acknowledge the receipt of an event from DSRIP. Note: the acknowledge back to DSRIP is different from the event response.	
ROM-DI-60	ROM shall send a response to DSRIP on an event after all the control actions have resulted in a response, i.e., all vendor-specific microservices have received responses. The structure of the response is as follows: 1. Household Id 2. Event Id 3. Status	
ROM-DI-70	ROM shall use the following logic to send a completion status to DSRIP: 1. If all vendor-specific microservices respond with a COMPLETE status, then status=COMPLETE. 2. If one or more vendor-specific microservices respond with an ERROR status, then status=INCOMPLETE. 3. If one or more vendor-specific microservices have not responded after N minutes, then status=TIMEOUT	ROM-DI-60

Source: EPRI

Persistent Configuration Storage

See Table B-3.

Table B-3: Residential Orchestration Module Requirements for Persistent Configuration Storage

Requirement Number	Requirements Text
ROM-PCS-10	ROM shall persist the configuration information that is provided at the time of ROM "creation". The types of configuration information provided at the time of "creation" are: 1. Household Id 2. Device list in the household including {Manufacturer, Model, Device Id} 3. Authentication information for accessing data for vendor-specific microservices.
ROM-PCS-20	ROM "creation" process shall instantiate the necessary vendor-specific microservices and all the invariant components of the ROM.
ROM-PCS-30	ROM shall persist authentication and authorization and access tokens that are necessary for various vendor-specific APIs

Requirement Number	Requirements Text
ROM-PCS-40	ROM shall persistent rate-signal information received from DSRIP for scheduling consequent control actions.
ROM-PCS-50	ROM shall persist statuses of event responses received by vendor-specific microservices in response to scheduled control actions for an event.
ROM-PCS-60	ROM shall persist the opt-out state of a household/customer that is within the purview of the ROM.
ROM-PCS-70	ROM shall persist in the "last known state" of the devices that are affected by an event in case the opt-out is received after the start of the control action and the control actions had to be reversed.

Source: EPRI

Scheduling Engine

See Table B-4.

Table B-4: Residential Orchestration Module Requirements for the Scheduling Engine

Requirement Number	Requirements Text	Related to
ROM-SE-10	ROM shall schedule control actions for events received from DSRIP for each household. Note: scheduling control actions may require actions to be taken a few "hours" before the actual event time, e.g., pre-cooling HVAC before the peak-rate period.	
ROM-SE-15	ROM shall update the scheduled control actions when it receives an event opt-out from DSRIP. If any control actions are currently underway at the time of receiving the opt-out, then ROM will attempt to reverse the control actions by setting the impacted device to its "last known state".	
ROM-SE-20	ROM shall schedule data acquisition from vendor applications periodically for each household.	
ROM-SE-30	ROM shall schedule data acquisition from various sources once every hour with a minimum sampling rate of 15 minutes (4 data points per hour) just after the completion of the hour, e.g., schedule data acquisition for the 9 am hour at 2 minutes past 10.	ROM-SE-20

Source: EPRI

Orchestration Engine

See Table B-5.

Table B-5: Residential Orchestration Module Requirements for the Orchestration Engine

Requirement Number	Requirements Text
ROM-OE-10	ROM shall use the following orchestration workflow for aggregating data from vendor cloud applications and sending the data to DSRIP and Chai Pro: 1. If it is time for data collection, begin the data collection loop. 2. Loop through each household under the purview of this ROM and perform the following tasks: 2.1. Loop through each device data source (cloud app, local EMS, etc.) that is part of the list of devices in that household and perform the following tasks: 2.1.1. Get data from the aggregation engine 2.1.2. Persist the fetched data locally 2.2. End Loop over devices 3. End Loop over households 4. End data collection loop. 5. Package data for sending to DSRIP and Chai Pro consistent with the APIs through DI and CI components. 6. Send data to DSRIP and Chai Pro through DI and CI components. Note: the specifics of getting data from 3rd party sources and time normalization are documented in the aggregation engine section.
ROM-OE-20	ROM shall use the following orchestration workflow for sending control signals to vendor cloud applications and receiving feedback for control actions: 1. Is it time to send out control signals to vendor applications? 2. Loop through each household under the purview of this ROM for which the user has not opted out and perform the following tasks: 2.1. Loop through each device application (cloud app, local EMS, etc.) that is part of the list of devices in that household in the order of priority expressed and perform the following tasks: 2.1.1. Change set points in advance of event start based on device type, e.g., HVAC needs to go through pre-cool/pre-heat, HPWH to go through pre-heat, energy storage to go through discharge/pre-charge, etc. 2.1.2. Wait for response from the cloud application. 2.1.3. Collate the response obtained from the cloud application. 2.2. End Loop over devices 3. End Loop over households 4. End event control loop.

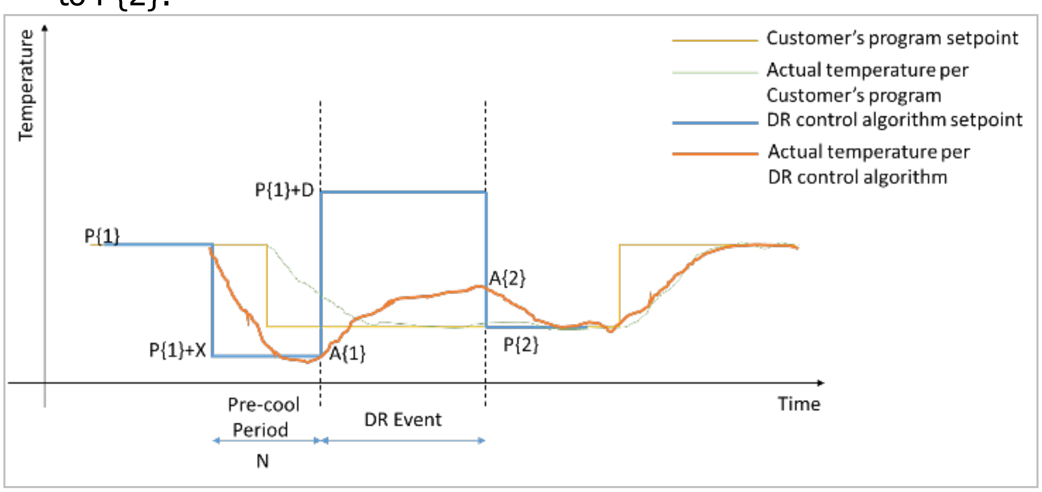
Requirement Number	Requirements Text
	5. Package response data for sending to DSRIP consistent with the APIs. 6. Send event response to DSRIP.

Source: EPRI

Control Engine

See Table B-6.

Table B-6: Residential Orchestration Module Requirements for the Control Engine

Requirement Number	Requirements Text
ROM-CE-10	ROM shall implement a variety of control algorithms for effecting control actions that are dependent upon the device/class of devices that are being controlled. The following class of devices is covered in R1.0: 1. HVAC – control is driven through thermostat set point adjustment 2. HPWH – control is driven through direct set point adjustment (for CTA 2045 compatible devices) 3. Energy Star appliances – control is driven through appliance-provided DR method (e.g., Delay Appliance Load / Temporary Appliance Load Reduction). 4. Battery / Storage – control is driven through collocated EMS.
ROM-CE-20	ROM shall implement a "pre-cool/heat", "post-cool/heat" algorithm for control of HVAC and HPWH set points. The algorithm is described as follows: 1. N hours before the start of DR event (or rate change event), change the set point to the programmed setpoint(P{1}) + X. 2. During the event, change the set point to P{1} + D. 3. After DR event (or rate change event) ends, change the set point back to P{2}. 

Requirement Number	Requirements Text
	Note: In keeping with customer preferences, the values of 'X' and 'D' are to be defined and adjusted such that A{1} and A{2} (the actual temperatures during pre-cool and DR periods) do not exceed the comfort thresholds set up by the customer. Note 2: For the case of pre-cool, as shown above, the value of X is negative and D is positive. In the case of set points for HPWH and for pre-heating, the values of X are positive and D is negative.

Source: EPRI

Aggregation Engine

See Table B-7.

Table B-7: Residential Orchestration Module Requirements for the Aggregation Engine

Requirement Number	Requirements Text	Related to
ROM-AE-10	ROM shall aggregate data from various vendor applications (cloud, Local EMS, etc.) through appropriate Vendor Specific Microservices.	
ROM-AE-15	ROM AE shall request a given vendor-specific microservice with an indicator for the interface to be used to obtain data, especially if the vendor application supports multiple interfaces for data acquisition, e.g., current data vs. historical data.	ROM-AE-10
ROM-AE-20	ROM shall perform data integrity checks and data clean-up of the data received from the vendor-specific microservices: 1. Is the data received a "state" variable or a "continuous" variable? Examples of "state" variables include enumeration values, strings, and non-numeric data. Examples of "continuous" variables include numeric data such as temperatures, humidity, etc. If the "continuous" variable are the values in a "reasonable" range? 1.1. Is the data the right sign (positive/negative)? 1.2. Is the data outside a reasonable range? 2. If the data are a "continuous" variable, are the "zero" values real 0's or are they "NULL" (or N/A). 3. If the data has "NULL" are the "NULL" values possible? 3.1. "NULL" values are possible for data from devices that are not provisioned or have not been correctly configured. 4. Flag the data that does not conform to the integrity checks above.	

Requirement Number	Requirements Text	Related to
	5. For data that are flagged, if the data are a "continuous" variable, then use imputation rule(s) to back-fill the data. 5.1. A default imputation approach for data is to hold the data at a previously known "good" value.	

Source: EPRI

Vendor Specific Microservices

See Table B-8.

Table B-8: Residential Orchestration Module Requirements for Vendor-Specific Microservices

Requirement Number	Requirements Text
ROM-R1.0-VSM-10	ROM shall use vendor-specific microservices for obtaining data from vendor applications (cloud, local EMS, etc.) and for effecting DR control signals (e.g., set point changes).
ROM-R1.0-VSM-20	Each VSM in a ROM shall include an interface controller that helps to mediate the transactions between ROM and the vendor-specific application.
ROM-R1.0-VSM-30	Each VSM interface controller shall perform the following tasks: 1. Use appropriate interface methods to access data. 2. Use appropriate interface methods to effect DR control tasks. 3. Verify the data received from vendor-specific applications for schema validity. 4. Verify the response received from vendor-specific applications for control tasks for errors. 5. Implement error relief mechanisms such as retries. Default approach is to retry 3 times before propagating the error to the Aggregation Engine and Orchestration Engine. 6. At the time of VSM "creation", verify connectivity to the vendor application using the credentials provided to the ROM. 7. Communicate necessary tokens and other task-critical data to the ROM PCS. 8. React to error messages resulting from token expiration by acquiring a new token wherever possible.
ROM-R1.0-VSM-40	ROM shall use the following vendor-specific API calls for data acquisition:
ROM-R1.0-VSM-50	ROM shall use the following vendor-specific control API calls for effecting DR control:

Source: EPRI

CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix C: Open Demand Side Management Resource Integration Platform Configuration and Design

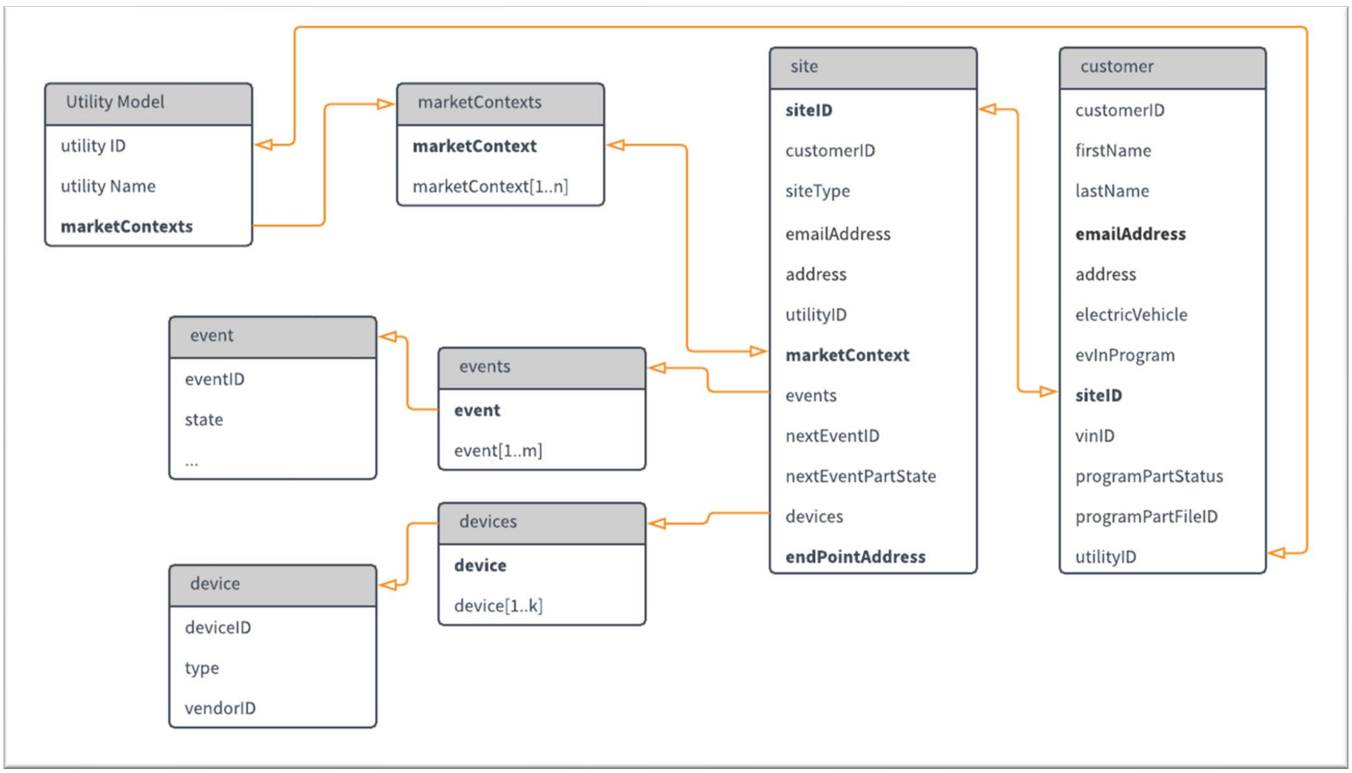
June 2024 | CEC-500-2024-079-AP

APPENDIX C:
Open Demand Side Management Resource Integration Platform Configuration and Design

The OpenDSRIP platform configuration and design consists of three main components: (1) a normalized data mapping module; (2) interface design plan; and (3) a data visualization plan. This Appendix provides greater detail on each of these three main components.

The implementation of the OpenDSRIP platform uses a normalized data model that maps various entities that are designed using an approach depicted in Figure C-1.

Figure C-1: Mapping of Entities Part of Open Demand Side Resource Integration Platform Design



Source: EPRI

Table C-1 provides details on the site data model.

Table C-1: Site Data Model Configurations in Open Demand Side Resource Integration Platform

Entity Model Field	Description	Type; Example Values
Site ID	DSRIP ID for the site associated with the program participant that is part of the DSRIP-based Utility Rate Program.	String (GUID); 2f55b2d9-7079-47de-a264-40f37695c5dd
Customer ID	Chai provided a customer identifier for the site.	String (GUID); 99873804-9129-4336-9413-bf8e6eb0ae96
Site Type	The type of the site.	String; Residential/Commercial/EV.
Email Address	Email address of program participant that manages the sites.	String; jdoe@example.com
Address	Site address if Site Type is "Residential or Commercial". Address of the EV owner if Site Type is "EV".	String; 101 Nameofstreet Ave, Nameofcity, CA zipcode.
Site Utility	Utility that serves the site if Site Type is "Residential" or "Commercial". If Site Type is EV, the utility that serves the EV owner's residential or commercial site.	String;PG&E.
Site Utility MarketContext	The Market Context Identifier associated with the Site and utility.	String (GUID); 21c4dfff-ef03-4cd2-9413-40f376953f21
Events	An array of events that have impacted the site.	Array;[1 or many Event Fields]
Event	An associative array of keys and values.	Array; [KEY => VALUE], for example, ['event ID' => '21c4dfff', 'participation state' => TRUE, 'completion state' => 'COMPLETE']
Next Event ID	The next DSRIP Rate Change Event scheduled for the site.	String;
Next Event Participation State	Participation state of the site in the upcoming event. Note that the default state is TRUE meaning that the site participates in all Rate Change Events by default. When user signals to DSRIP (through Chai App) that they Opt-Out, this was set to FALSE.	Boolean; TRUE.

Entity Model Field	Description	Type; Example Values
Devices	An array of data-providing devices associated with the site.	Array; [1 or many Device Fields]
Device	An associative array of keys and values.	Array; [KEY => VALUE], for example, [‘device id’ => ‘1FVACXDT0FHGJ3519’, ‘type’ => ‘thermostat’, ‘vendorID’ => ‘ecobee’]
End-Point Address	End-point address of the delegated system (ROM, OVGIP, Energy360) associated with the Site. Note: for ROM, the end-point address may vary from Site to Site.	URL; http://OpenDSRIP.org/rom/<romID> Note: romID is a GUID.

Source: EPRI

Open Demand Side Resource Integration Platform’s Configuration and Design Specifications

This section provides a set of configuration and design specifications for the development of OpenDSRIP. The configuration and design specifications specifically address aspects of the OpenDSRIP and ROM including data models, data partitioning, interface specifications, software object models, and potential Graphical User Interface sketches.

Data Visualization Tools Enabled by the Open Demand Side Resource Integration Platform

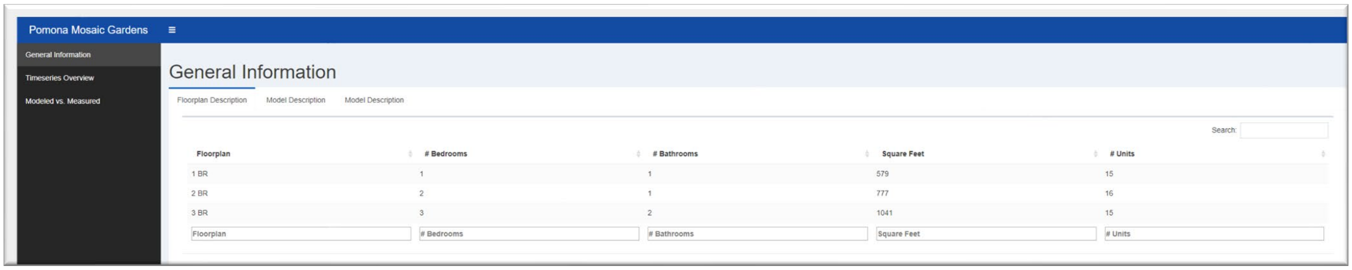
The following is a set of use cases to address a set of research questions provided by OpenDSRIP visualization tools.

The project team developed a set of use cases through its experience working on field demonstrations integrating various BTM DERs. All use cases have a data tooltip and the ability to download the visualization in multiple data or image formats. In addition, the dashboard is updated monthly as new data is collected from the field site. The following sections will show an example of each use case in both a community and sub-community level context from a variety of sites.

Use Case: General Information

Important meta-data about the community is provided in tabular format. The tabular design allows for both global and column-only searches. See Figure C-2

Figure C-2: General Information Visualization

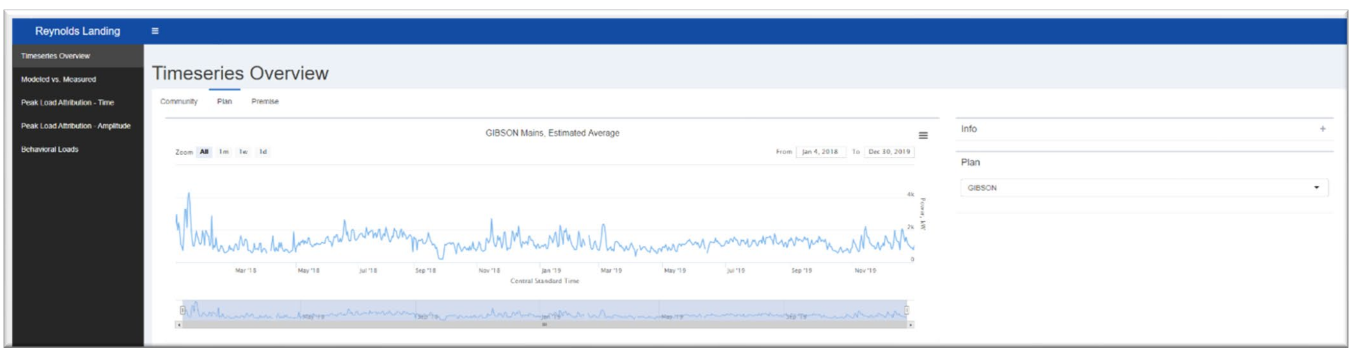


Source: EPRI

Use Case: Timeseries Overview – Community Level

The community scale visualization is used for community data visualization. This provides data in a timeseries overview that can be filtered based on different timescales. In this use case, the user can zoom the timeseries visualization using the top left buttons to the following windows: 1 month, 1 week, and 1 day. The user can also choose are arbitrary date window with the date selection boxes at the top right. Finally, the user can scroll through the timeseries with the time slider at the bottom of the visualization. Note that this community only has mains data for reporting. See Figure C-3.

Figure C-3: Timeseries Overview – Community Level Visualization



Source: EPRI

Use Case: Modeled versus Measured

This use case shows data visualization in the form of a comparison of the site-level data to energy simulations based on the site's design specification. The aggregated home-level data is being compared to one of seven energy simulation models completed as part of this particular community. The first model option is the community as-built – meaning the model depicts estimated energy simulation data. The six other model options hypothesize end-use energy use for all electric replacement measures and all gas replacement measures under three different California Title 24 standards from 2013, 2016, and 2019. The goal is to understand how these communities are performing compared to their energy simulations. See Figure C-4 for community-level visualizations. The figure details the ability to group sites based on meta information – in this case floorplan.

Figure C-4: Modeled versus Measured – Community Level Visualization

Source: EPRI

Use Case: Modeled versus Measured – Average Floorplan Level

Figure C-5 demonstrates the Model versus Measured use case at the average floorplan level with the addition of the floorplan selection button.

Figure C-5: Comparison of Operational Data to Energy Simulations based on Floor Plan

Source: EPRI

Note that end-use load shapes can also be disaggregated as many of these communities provide circuit-level metering or other forms of disaggregation tools. This is to better attribute energy impacts to specific end-use loads.

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix D: Energy Data Warehouse and Functional Testing of the Open Demand Side Resource Integration Platform

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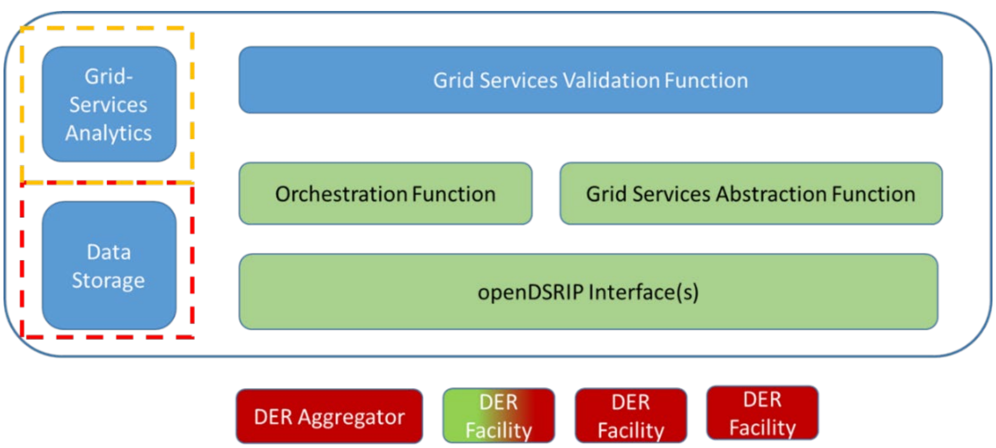
APPENDIX D:
Energy Data Warehouse and Functional Testing of the Open Demand Side Resource Integration Platform

This appendix includes a section on each of the three main tasks.

- How data is stored on each of the individual sites.
- How data is transferred from a site to the energy data warehouse.
- What "data" is collected from each connected device/customer side and owned distributed energy resource and how it is collected.
- An example site associated with this project and what and how data is collected.

Figure D-1 shows overall grid service functions enabled by OpenDSRIP that are covered in additional detail in previous Subtasks reports. This report will focus on the data storage (indicated by the red dashed square) components that energy grid services and customer analytics (orange dashed square).

Figure D-1: High-Level Architecture of the Open Demand Side Resource Integration Platform

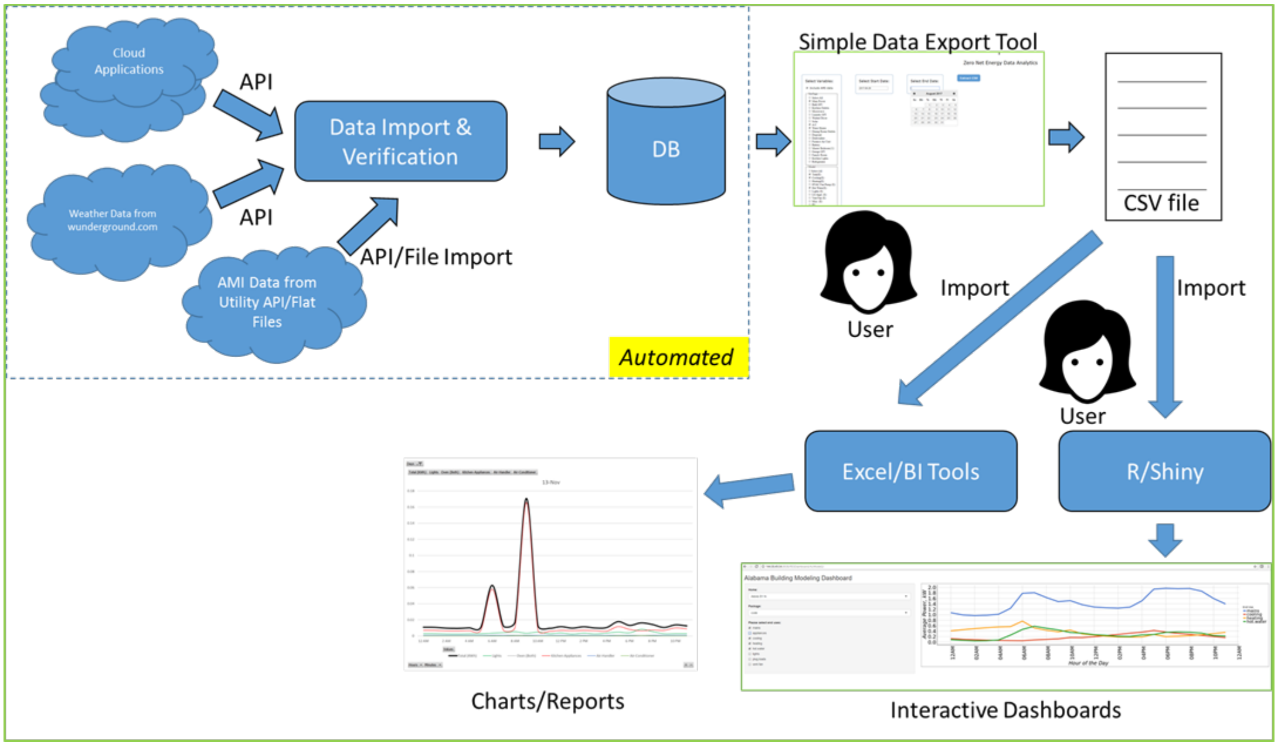


Source: EPRI

Data Storage

To ingest, normalize and extract data associated with the demonstration sites associated with this project, the project team uses a system that is commonly used with similar projects that EPRI is conducting across the country. shows a canonical data import architecture that is adopted for most data that is housed and analyzed in the broader AEC initiative. Across most AEC projects, data that is typically available through vendor-specific cloud-APIs or via flat-files and auxiliary data such as weather, AMI data, etc. are imported through vendor/project-specific import routines (part of the Data Import Library). The data verification ensures a certain level of data checking (against APIs/Schemas as appropriate) before the data is housed in the database. See Figure D-2.

Figure D-2: Data Import, Extraction and Visualization Schema Used for the Open Demand Side Resource Integration Platform

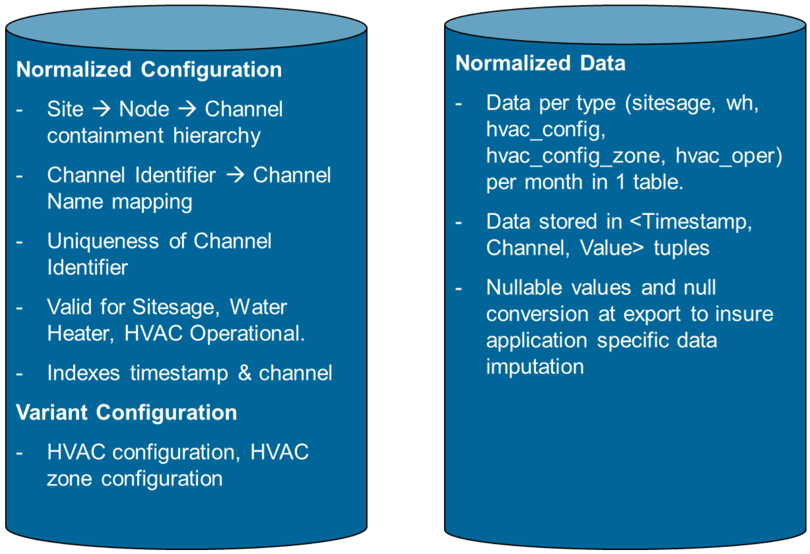


Source: EPRI

All data collected from the demonstration sites were normalized to a certain extent. Most of the normalization is automatically achieved through automated database management. Of particular importance is the overarching containment hierarchy that works well across a variety of residential/small commercial locations (Site → Node → Channel paradigm). Additionally, each type of data has a mapping of Nodes → Channel Identifier → Channel Names.

Figure D-3 shows the database (configuration and data) normalization that is current and present in the database. Of particular note, is that there is no explicit mechanism to "time normalize" the data in the database. The overarching engineering guideline is for the data to be "as true as possible" to the source. Hence, transformations (for example, data type conversions of Booleans to integer enumerations to integer, null to 0, etc.) are not typically performed. Instead, the database uses null able values wherever possible, and the data export tool takes care of providing a null representation (currently it is the literal "NA") so that analytical tools used by analysts can perform appropriate null transformations.

Figure D-3: Current Data Configuration



Source: EPRI

Extraction of data from the database to an analytical dataset is enabled through a simple yet flexible data export mechanism that provides normalized (null normalized) analytical datasets in csv format (or in zipped csv format for data spanning multiple types). This data can be imported into many different analytical tools for performing a variety of applications ranging from Interactive Dashboards (such as those enabled via R/Shiny extensions) to static descriptive analyses (via Excel) to predictive modeling (via Python numpy, scipy, TensorFlow).

Data Collection, Data Commissioning and Data Transfer

Integration of all products that can serve as load management systems and load monitoring tools has been of interest to many energy companies and third parties over the last few years. As these product leverage competing standards, ecosystems, and infrastructures (if at all) the project team attempted to complete the data monitoring task by using a "bottom-up" approach to aggregate as well as transfer data to a consolidated database for analysis. It is important to note that in this project, the project team typically did not "pre-select" residential DERs that would be used as part of this project. A site or community provider was not discouraged from working from existing manufacturers and trade allies as this: (1) simulates the current state of customer appetite for particular connected technologies, (2) represents current technical and implementation barriers that can only be identified during scaled demonstrations, and (3) establishes a baseline and benchmark for what controls can be enabled by connected technologies and what data can be collected to validate that control schema has been realized.

For this project, it was important to either minimize potential customer issues attributed to intermittent broadband connectivity and sometimes lost internet connectivity or recognize that device connectivity attrition attributed to loss of broadband connectivity in the period of performance of this project. In addition, it is important to gain customer consent for these projects. The latter was usually the approach in demonstration projects.

Gaining Customer Consent

Gaining customer consent is important to ensure successful data collection so that the project team has access to the data associated with project demonstration sites. Please see Figure D-4 for an example customer agreement.

Figure D-4: Example Customer Agreement

ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

CALIFORNIA CUSTOMER-CENTRIC DEMAND MANAGEMENT DEMONSTRATION

Program Participation Enrollment Agreement

Name: ____________________ Phone Number: ____________________

Email: ____________________

Street Address: __________ Apt. ______ City: __________ State: ______ Zip: ______

System Installed: ____________________

1. I am voluntarily enrolling in the California Customer-Centric Demand Management using Load Aggregation and Data Analytics Demonstration (Study) to be administered by the Electric Power Research Institute, Inc. (EPRI) and its technology provider, Intech Corporation and Chai Energy. (The Partners) as is described more fully below. In exchange for my participation in the Study, an energy management system (EMS) has been installed and will be maintained for the above party at the referenced location. The EMS, as well as the installation thereof, will be at no charge to the undersigned. The term of participation begins January 1, 2018 and ends December 31, 2019, with the test period for the Study scheduled to begin on commencement of participation and end on or before September 30, 2019. In consideration for the EMS being provided at no charge to the undersigned, I hereby consent, until December 31, 2019, for The Partners to install and service and for EPRI extract data from the EMS at no charge to any of them until the undersigned unenrolls from the Study or December 31, 2019, whichever comes first. No warranties are provided by with respect to the Study or the EMS. The electrical cost of service for operation of the EMS, and any removal after December 31, 2019, will be at your expense.
2. During the undersigned's participation in this Study, the undersigned will agree to setup and maintain a local Wi-Fi network at its expense to either allow the EMS to be connected to the Internet through my Wi-Fi network or to wirelessly transmit information over other wireless networks as may be selected by EPRI or The Partners. The undersigned agrees to allow Study-related data to be transmitted over these wireless networks during my participation in the Study. I will call EPRI's Program Manager, Ben Clarin, 650-855-2317, if I am aware that the EMS is not working or is disconnected if our Wi-Fi network is non-operational, or if help is needed to reconnect the EMS, or if electric service is out. In all instances, the undersigned agrees to exercise the same reasonable care over the EMS that is exercise over equipment owned by the undersigned, and the undersigned will not intentionally damage or alter the EMS during the Study.
3. The undersigned understands that one purpose of this Study is to generate data to help EPRI and EMS understand how anticipating customers manage their electricity use pursuant to cooperative research award granted to EPRI by the California Energy Commission (CEC). The undersigned agrees that it will not be entitled to any financial consideration for participation in the Study, but that the data collected is important to the Study.
4. The undersigned agrees, as part of voluntarily participating and for the consideration received under this Study, to answer all questions and surveys that EPRI and The Partners present to me, in good faith and to the best of our ability during participation in the Study. I understand and agree that certain personally identifiable information (PII) including my name, home address, apartment number, and utility customer account number may be collected. I hereby do grant EPRI, and The Partners the right to use and share this PII with each other for any method or purpose, but it is NOT intended to be made public. The undersigned understands that administrative, technical and physical safeguards may be used to protect the undersigned's information, including industry standard methods to protect that information. However, the undersigned recognizes that no system is completely secure or "hacker proof." The undersigned also understands that it is also responsible for taking reasonable steps to protect its personal information against unauthorized disclosure or misuse. The undersigned understands that EPRI or The Partners may be required or compelled by law to release the information extracted from the EMS which may include, but is not limited to, the undersigned's gas or electric equipment operation, temperature set points, overall energy usage and my customer attributes and behavior. I understand and agree that this information may be analyzed and derived to create results that may be reported separately or in the aggregate from other Study participants, and these results will be made public. I understand and agree that EPRI, CEC and The Partners and their agents are beneficiaries of this Agreement; with the right to use, publish, publicize and make multiple derivations from the undersigned's information.
5. If the installed Wi-Fi components of the EMS cease working or the undersigned wishes to no longer participate in the Study, I will call the Program Manager referenced above. In response, we may be contacted by EPRI or The Partners (by phone, email, or other means) to have our equipment reconnected, repaired, replaced or removed. The undersigned will provide the subcontractor or technician with reasonable access to the above referenced location for the free service of the device, thru December 31, 2019.
6. If during the Study the undersigned relocates from the above premises, or these premises are leased to another entity or person, then the undersigned agrees to call the Program Manager prior to our move-out to provide notice about the move. The undersigned also agrees that if another entity or person takes possession of the premises during the Study, then they will be informed of the Study and that their occupancy is subject to this agreement by providing them with a copy of this document prior to their move-in.
7. The undersigned acknowledges that the responsibility and liability is limited to EPRI and The Partners and their agents for the installation of the EMS and Wi-Fi, and it is further acknowledged that this specifically excludes losses of all types including but not limited to personal injury, property damage, bodily harm, death, third party liability or any other claim, cost or expense directly arising out of the operation of gas and electric appliances and other equipment situated at the above location. Further, the undersigned understands and agrees that to make a successful claim for losses due to the installed EMS, that the undersigned must first contact The Partners, or the EMS component part manufacturer's warranty department for resolution and if not, this will void the undersigned's right to claim to losses. The undersigned understands that it has the responsibility to manage and pay for the energy consumption of gas and electric appliances and equipment and all other energy-using items at the above referenced location.

By signing below, the undersigned *does certifies that it is the occupant or authorized representative of the above listed entity at the referenced address, who has read these terms and conditions in this Agreement, and understands them, and agrees to be bound by them. (If any questions, please call the EPRI Program Manager at 650-855-2317)*

Site Host's Authorized Signature: ____________________ *Date:* ____________

Source: EPRI

To collect the necessary customer agreements, the project team worked with the developers, homebuilders, and business owners to determine ideal processes to maximize the data being collected in each of these individual sites. These scenarios of getting customer approval at the time closing papers are signed, or at the time a tenant moves into a unit, provide usually a high success rate. In new construction and/or home ownership instances, the project has had success in receiving customer agreements (100 percent agreement in a similar demonstration) but contingency plans/additional recruitment activities can be developed in the event of considerable opt-outs.

Communication to Enable Data Transfer

In successful communication and data transfer of mass-market connected devices, it is important to understand the implications as they pertain to lack of consistent broadband connectivity associated with reliance on customer Wi-Fi. See Table D-1.

Table D-1: Offline Analysis of Utility-Scale Smart Thermostat Pilot in the Midwest

	2015 (Average)	2016 (Average)
Offline	6.8%	14.4%
Unknown	4.2%	2.6%
Totals	10.9%	17.0%

Source: EPRI

Table D-1 provides a representation of the expected impacts of the loss of data collection and communication associated with leveraging consumer Wi-Fi. To summarize:

- Short-term data communication loss of ~10 percent. As Table D-1 shows, typical data loss from large-scale demonstration projects indicates that a project team can expect approximately 10 percent of consumer-connected devices to lose connectivity at any given time, resulting in loss of data collection of that device for a particular project.
- Long-term device attrition of around ~6- to 10 percent. Long-term device attrition as a result of actions such as customer replacement of Wi-Fi routers and forgetting to re-establish connected device connection could result in complete loss of device connectivity when a device is participating in an energy load management program. Results from the utility program shown in Table D-1 show device attrition of 6 percent over one year.

As a result, based on factors such as: (1) value of data collection, (2) site provider's consent, (3) minimizing site occupant impact, and (4) overall project budget was taken into account and assessed on a site-by-site basis on whether or not to leverage consumer Wi-Fi for particular sites associated with this project. Results are detailed in subsequent chapters of this report. If customer Wi-Fi is leveraged, the following data loss risk management strategies were implemented.

- Application of data analytics/data cleaning techniques in the event of short-term data loss: The project team will implement methodologies in which to fill in data that is lost on a short-term basis. These include:
  - Linear interpolation fills in data points in the event of short-term data loss based on data received. This can be done for parameters such as environmental data including indoor temperature collected from smart thermostats.
  - Forward filling of data points in the event of short-term data loss based on data received. This can be done for parameters such as temperature setpoint for connected devices such as smart thermostats and connected water heaters.
  - Data omission and estimation in the event of short-term data loss. If data cannot be linearly interpolated, forward filled or any other method of data cleansing, data from that parameter from that particular site was omitted. In its place, averages of the same data parameters of other units, homes, etc. found in that particular site.
- Customer outreach in the event of long-term data loss. In the event of persistent data loss for a particular site, the project team is working w/ site providers to develop metrics and methods of communication w/ occupants in the event of long-term data loss. It is important to note that tenant/occupant wishes will mostly take precedence in the event of long-term data loss and data cleaning tools and tactics such as data estimation was completed.

Functional Testing of the Open Demand Side Resource Integration Platform

OpenDSRIP system-level functional testing uses test data for emulating data delivery from behind-the-meter sources and a set of high-level use cases. See Table D-2 for test data required for functional testing and Table D-3, which discusses functional tests and use cases.

Table D-2: Test Data for Open Demand Side Resource Integration Platform Functional Testing

Test Data Set	Source
Sites data	1. Residences: Anonymized data from 10 different residential sites. 2. Commercial: Anonymized data from 3 different commercial facilities. 3. EV: Data from 5 different EVs provided by a previous EPRI EV Study with anonymized VIN information.
Customer data	Simulated customer data with random 1:1 assignment between customer and site.
Utility data	Simulated utility data for 2 different utilities each with 2 different market contexts. Random and relatively uniform associations of <Utility,marketContext> to <customer, site>

Test Data Set	Source
User data	Simulated user accounts for testing purposes. Two users each belonging to different simulated utilities.
Devices data 1. HVAC Data 2. HPWH Data 3. Inverter Data 4. Circuit level Data 5. AMI Data	1. HVAC Data – re-purposed ecobee data from another EPRI thermostat study for 3 months. 2. HPWH Data – re-purposed Skycentrics data from another EPRI HPWH study for 3 months. 3. Inverter Data – simulated data based on SolarEdge API. 4. Circuit level data – data from ZNE homes for 3 months 5. AMI Data – anonymized data from ZNE homes for 3 months.
Events data	4 different rate structures Tiered, TOU, CPP, and day-ahead Locational Marginal Pricing (LMP) resulting in dynamic day-ahead pricing changes; 20 events generated randomly within the 3-month window for which data is defined; includes rate scenario specific pricing signals generated in openADR2.0B XML structure.

Source: EPRI

Table D-3: Test Use Cases for the Residential Orchestration Module found within the Open Demand Side Resource Integration Platform

Test Use Case	Definition
DSRIP reacts to a TIME Server signal	This tests the openADR2.0B VEN functionality where DSRIP reacts to receiving a TIME Server (VTN) signal.
DSRIP receives data from Orchestration Modules	This tests the ROM and commercial BEMS sending data to OpenDSRIP and having the data in the data store.
ROM reacts to a pricing event	This tests a ROM that reacts to the receipt of a pricing signal event from OpenDSRIP.
ROM schedules control actions	These test the ability of the ROM to schedule control actions on devices in behind-the-meter IoT and DER.
Customer gets notified of upcoming rate-change events	These test the customer receiving notification based on a scheduled rate-change event.

Signal Dispatch and Demonstration

To finalize an end-to-end test of the overall flow of information from the OpenDSRIP VTN to the behind-the-meter DER through OpenDSRIP and orchestration modules, TIME Server signal dispatch and demonstration scripts were set up.

The demonstration setup is shown in Table D-4.

Table D-4: Demonstration Setup for Transactive Signal Server Signal Dispatch Demonstration

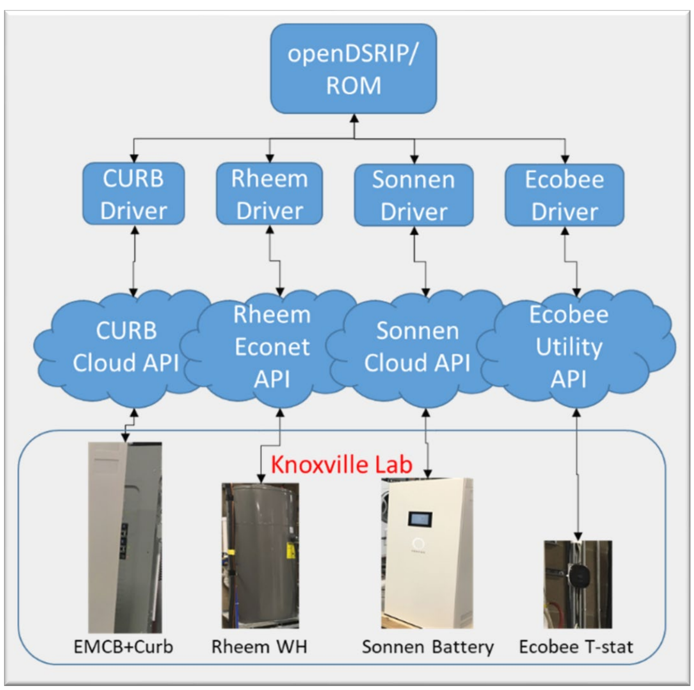
Site Location	Site Name	Market Context	Type of Event	Control Entity	Control Action
Pleasanton, CA	R&D Office	DLAP_PGAE_APND	PG&E DR Event	Energy360 & User Behavior	1. Rule-based offset for thermostats when DR event is called. 2. Notification when price exceeds the threshold.
Clovis, CA	Envision Homes by DeYoung	DLAP_PGAE_APND	Peak price	Residential Orchestration Module	Coordinated control of: 1. smart thermostat, 2. connected water heater, 3. customer batteries.

Source: EPRI

Laboratory Evaluation of Coordinated Control of Distributed Energy Resources

The laboratory evaluation of coordinated control is conducted using a setup shown in Figure D-5.

Figure D-5: Open Demand Side Resource Integration Platform Coordinated Control Laboratory Setup



Source: EPRI

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Appendix E: Accessing Scalability of Approaches to Enabling Buildings and Communities as Flexible Resources

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APPENDIX E:
Accessing Scalability of Approaches to Enabling Buildings and Communities as Flexible Resources

Chapter 2 presented this project's proposed framework to evaluate various combinations of mass-market Behind-the-Meter (BTM) Distributed Energy Resources (DER)s and how they can be aggregated together to provide grid or customer services – primarily driven by dynamic rate signaling using the following equation. Appendix E goes into detail on how this project proposes accessing scalability to enable buildings and communities as flexible resources.

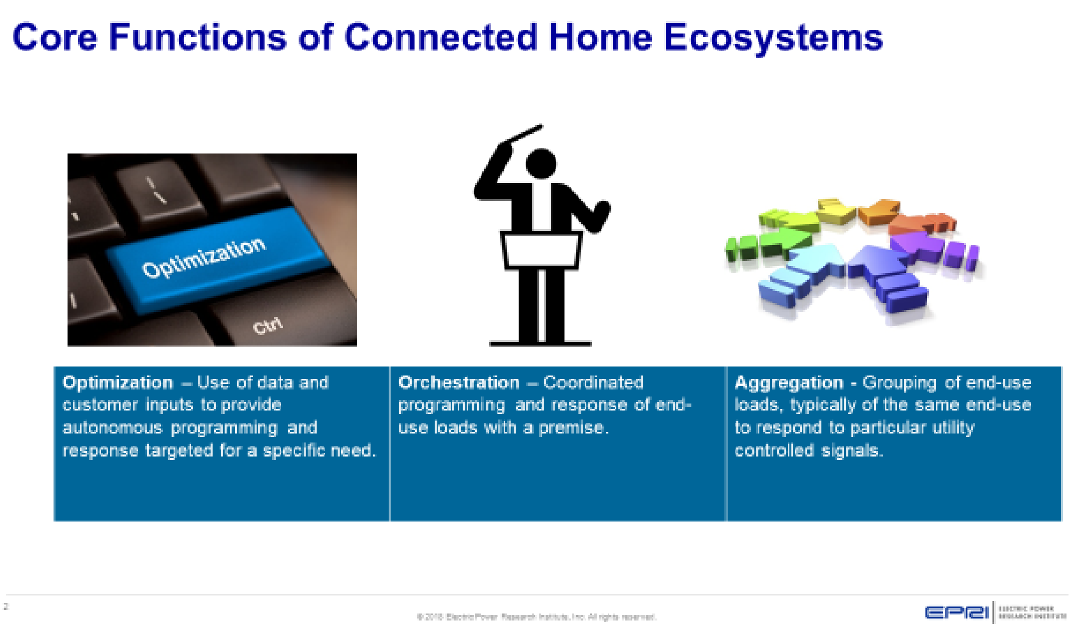
Evaluating Building and System Flexibility using Behind-the-Meter Distributed Energy Resources

Assessing scalability through a lambda function λ(x,t) further described in Equation 1 in Chapter 2 was accomplished in this project in two ways: (1) detailed monitoring of system and device installation processes, and (2) holistic understanding of data from devices to better understand operational performance of the system.

Defining Control of Behind-the-Meter Distributed Energy Resources

To begin to understand the value of a connected ecosystem, the project team defines three core functions that potentially can be used by the grid to control BTM DERs: (1) aggregation, (2) orchestration, and (3) optimization (Figure E-1).

Figure E-1: Core Functions of Behind-the-Meter Distributed Energy Resources



Source: EPRI

Aggregation

Aggregation as a core function in this report is defined as the grouping of end-use loads and systems and having them respond to utility signals – both control and price signals. Demand Response Management Systems (DRMS)s, Distributed Energy Resource Management Systems (DERMS) and other similar grid-facing platforms are current tools that provide a single interface to a utility or energy company and enable control of multiple devices found within an energy service territory. These systems have been around providing demand response (DR) programs for energy companies. Historically, these systems have been focused on aggregating similar end-use systems from multiple product providers. As a result, it was not uncommon for a single utility to have multiple aggregation platforms to enable customer choice of different product providers or enable different customer-sited DERs (D. Logsdon 2016). Several utilities across the country have investigated and implemented platforms aggregating multiple customer-sited DERs for operational improvements in conducting residential demand response programs. All efforts try to achieve the fundamental goal of aggregating mass-market BTM DERs.

There are several aggregators in the market already looking at leveraging BTM DERs as grid resources so this report will touch on enabling aggregation but focus on the other two core functions as they are of interest in coordinated control based on rate signaling.

Orchestration

Historically, utility programs have been focused on aggregation. However, as grid flexibility needs are now not only temporal but spatial as well, aggregation of a device may not be adequate to support a combination of grid and customer needs. In these events, there may present a need for coordinated control or response from multiple DERs within a premise. From a residential consumer's perspective, this function is enabled by home automation systems. Providers of home automation systems look to orchestrate the use of various devices for lifestyle needs such as security and entertainment. This project investigates how infrastructures to support orchestration for home automation can be leveraged for energy management orchestration.

Optimization

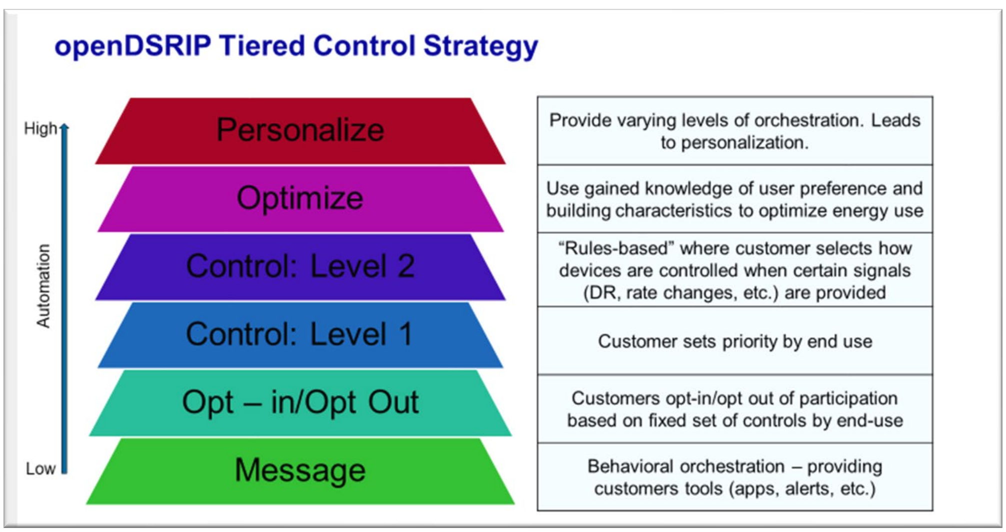
In this project, optimization can be defined as the use of some form of information through collected data to provide autonomous and targeted responses. Over the last few years, device manufacturers and associated service providers have collected data on their products to meet objectives such as: (1) reducing energy consumption, (2) improving comfort conditions and (3) identifying operational faults of specific equipment. Historically, optimization has been focused on the improved performance of devices or end-use systems. This report will look at optimization in a manner that investigates how dynamic pricing signals can potentially be used as a mechanism to optimize performance and use of BTM DERs or a combination of these DERs in a coordinated fashion within a building or community.

Subsets of Orchestration and Optimization

It is hypothesized that improving BTM DER controllability through aggregation, orchestration and optimization is a goal to enable better energy system flexibility. This is important as California tries to meet its decarbonization goals through electrification of the transportation sector and efficient electrification of the buildings sector. However, it is important to understand that optimization and orchestration, especially in the eyes of a large customer base, are usually not binary functions. This project team proposes subsets of orchestration and optimization, which are currently or could potentially be enabled by BTM DERs. These subsets are presented by technical complexity – from least complex to implement to most complex (Clarin 2018).

Figure E-2 presents a set of tiers in which single-device or multi-device orchestration and/or optimization happens. Behavioral orchestration consists of messaging using mobile applications or voice assistants and can be enabled by price/control triggers by an energy company. For example, a push notification via a mobile app can indicate a time in which electricity rates were higher than normal. What the user will do with that information is up to him or her. The other end of the spectrum is the use of historic data or advanced models to predict how a user and his/her energy systems will respond to energy company price/control triggers. For additional "tiers" of orchestration/optimization based on industry work, see Table E-1.

Figure E-2: Orchestration and Optimization Tiers (Based on Level of Complexity)



Source: EPRI

Table E-1: Definitions and Examples of Various Levels of Orchestration and Optimization

Orchestration Level	Definition	Example
Messaging	Providing messaging via mobile applications, text messaging and/or other feedback	Energy monitoring tools that contain both customer and utility information.

Orchestration Level	Definition	Example
	mechanisms that give customers energy-related information.	Orchestration through "behavioral" controls through targeted messaging.
Opt-in/Opt-out	DER are given a pre-set routine. Customer can choose whether or not they participate.	Most current device/DER programs are run under opt-in/opt-out conditions where a fixed control command is sent to an aggregate set of customers.
Prioritize	Customer is given some mechanism on which their participating DER will be opted out first.	Some home automation systems today provide a mechanism to define a priority of how DER will be opted out based on technology preference of the customer.
Rules/IFTTT	Customer gives DER within a premise a set of constraints in which a DER can operate under a control/rate event.	The backbone of If This then That (IFTTT)[1]-based platforms.
Optimize	"Set it and forget it." The ecosystem can receive utility price/ control signals and develop training data sets to how customers would respond to these dynamic price signals.	Many smart devices claim advanced optimization algorithms that learn customer tendencies/preferences. However, since residential smart homes and connected ecosystems are currently in their infancy, little is known about ecosystems that enable full energy-related smart home optimization.
Personalize	Optimizing orchestration based on historic customer data/ feedback. Platform has learned customer preferences over time and has provided orchestration levels tailored to preferences.	Systems have combined customer segmentation practices to enable personification with training data sets to cluster program participants and provide different levels of device orchestration.

Source: EPRI

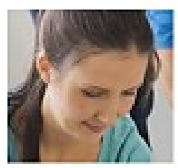
As previously discussed it is important to call out that: (1) orchestration and optimization are not binary phenomena in the eyes of the customer, (2) levels of technical complexity implementation vary, (3) data needs to successfully deploy at scale varies alongside technical complexity, (4) market readiness of BTM DERs to provide this level of orchestration within its ecosystem and part of a larger ecosystem is fairly nascent and varies from one product provider to another, and (5) potential risk of customer dissatisfaction as a result of leveraging the BTM DER as a grid asset varies.

[1] If This, Then That is a programming service common in home and building energy management that allows for simplified cause (the if) and effect (then) program of mass-market end-use technologies such as smart thermostats and connected water heaters.

It is important to note that as one moves up the proposed tiers of orchestration, from behavioral to personalization, it is proposed in this report that for DSM programs to realize mass market adoption, a utility or energy company should strive for personalization. The term personalization started appearing in the utility DSM space in the early-mid 2010s. In general, it can be characterized as tailoring or giving the perception of tailoring product and service offerings to a particular customer. As one may notice, personalization can potentially be achieved through an extensive understanding of a customer base. However, one may also notice that customer clustering and/or segmentation activities can be a potential first step to grouping a particular customer base to enable personalization. Clustering and segmentation can potentially be enabled and/or enhanced by the use of aggregation and then analysis of data enabled by a combination of connected ecosystems such as voice assistant platforms combined with utility data collected from current methodologies such as survey, billing and/or AMI disaggregation analysis. See Carradine (2018) for an example of a smart home manufacturer service provider's summary of its customer base.

Note that Figure E-3 shows various tiers of personalities. One can assume various orchestration and optimizations are necessary to trigger energy saving responses – from just sending behavioral messaging to full "set it and forget it" optimization strategies. As part of this project, the goal will not be to enable orchestration/flexibility (the Obj.(x,t) portion of the proposed framework) through improved optimization every time but assess its current state through a combination of secondary research, laboratory and field evaluations.

Figure E-3: Segmentation of Customer Base into Personas


ecobee Customer Personas	TECH JOSH	HOUSE-PROUD AMANDA	VALUE GREG
AGE	46	33	54
FAMILY	Married, 2 kids	Married, expecting 1st child	Married, 3 kids (1 at home)
HOUSEHOLD INCOME	$150,000/year	$120,000/year	$90,000/year
QUOTE	"I'm always on top of the latest trends in tech. I love trying out the newest gadgets and experimenting with how they work to improve my life.	"I take pride in making my home beautiful and comfortable for my family and friends. I want products that just work, and that improve our lives."	"I value my hard-earned money so I spend the time to compare product features and cost to make sure I get the most bang for my buck."
MOTIVATORS	Control, comfort	Beauty, comfort	Control, savings

Source: ecobee 2018.

Detailed Monitoring of the Technology Selection, Commissioning, and Installation Process

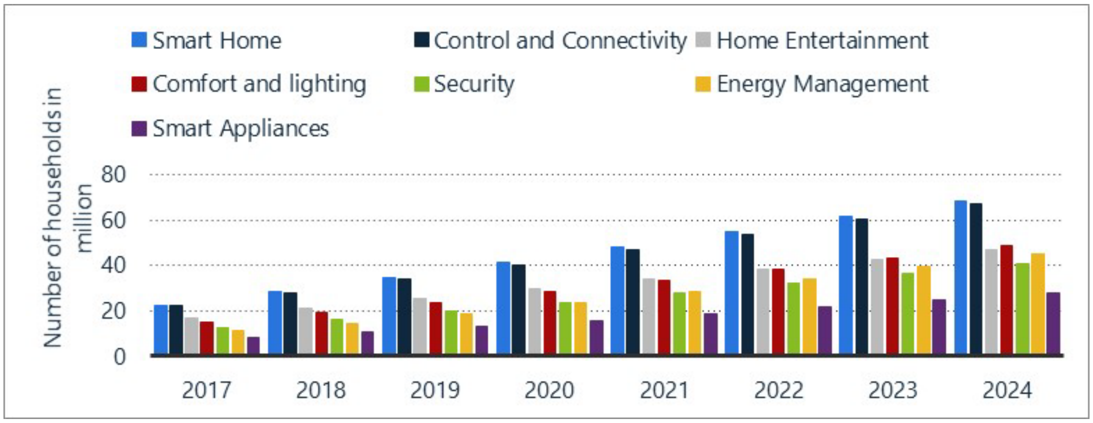
It is important to note that in many of these field demonstration projects, the selection of customer devices was made by the building manager, the home builder and/or the customer himself/herself. This is to proxy the market conditions. The project team has worked on projects where either commissioning of the system or customer selection caused a lack of persistence or challenges in enabling BTM DERs as reliable grid resources. For example, the selection of smart plugs for a device that does not typically operate during high peak prices or DR event times resulted in very little load shed in one residential project (EPRI 2019a). In another project, a connected HPWH was provisioned in a manner that limited its thermal capacity and its ability to store energy from grid use cases such as storing excess solar to be used instead of high-cost electricity during peak times (EPRI 2016a). Although this may be foreseen as an unideal scenario for the energy system, this was done by the plumber in a manner to prevent occupant scalding. It is important to always consider that these devices are customer systems that usually have a purpose other than being a DER to the energy system.

Detailed Understanding of Device Data to Understand Operational Performance and Customer Interaction

Customer data analytics in the energy space has typically focused on customer survey analyses, exhaustive submetering and, more recently, disaggregation and analyses of AMI data. See Harbor Research 2019.

Figure E-4 shows that smart homes with smart devices plan to continue to grow in the United States. However, reasons for procurement vary from enabling consumer control and connectivity to security to entertainment. Market penetration of advanced customer-sited communicating BTM devices provides the opportunity to collect substantial amounts of data that can potentially be used to supplement these traditional utility data acquisition methods. These systems inherently provide low-cost sensors that have the potential to collect device-level information at significantly lower costs and at greater granularity than traditional submetering techniques used to do energy analyses in the past. This is particularly impactful in residential and small commercial spaces where equivalent data streams have historically been rather costly.

Figure E-4: Number of Smart Home Devices in the US Installed by Application (2019-2023 are Projections)



Source: Continental Automated Buildings Association 2019

Data in the energy industry is usually assessed in silos. Energy companies and product providers did not need to exchange data with one another which results in limited transparency of what data is collected, stored and leveraged. In addition, concerns over customer security and privacy alongside data governance policies are in their nascent stages. Finally, there is not a clear value proposition and use case for the collection of not only AMI information but device-level information as well.

To assess value and opportunities when leveraging data made available by BTM DERs in the aggregate, this project will assess the industry by taking a two-step approach. The first step is to develop a framework for presenting potential value propositions of what type of insights data from BTM DER can enable when presented in aggregate. The second step is to assess the availability and access to this data from BTM DERs at the time this report was written. The second step was completed in Chapter 3.

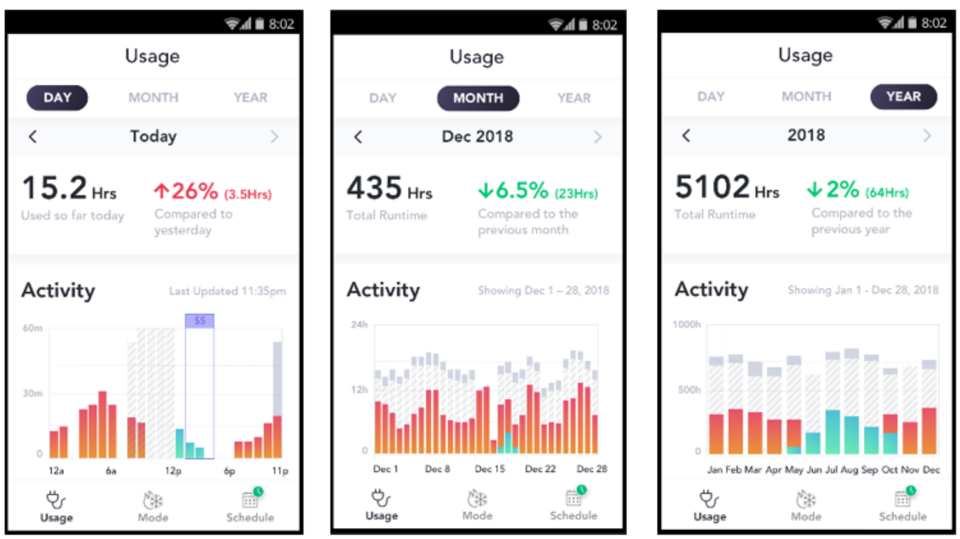
Classification and Evaluation of Connected Ecosystem Data

To assess the value of data for BTM DERs, this project will use a similar categorization method that it used to evaluate data from connected devices found in smart home offerings (EPRI 2016a). This section of the report will provide examples of these data parameters and then provide example benefits to both the market that it serves and the electric grid using grid signaling such as dynamic or transactive rates.

- **Availability Data:** Availability data can be defined as parameters or indicators that determine what devices or systems are controllable/available within a given premise or community. Availability data can be provided in the form of energy portal readings that identify which resources are available through APIs collected by third parties on device connectivity status. Note that the absence of data in instances where data is expected can also be used as a proxy for data availability. Availability data allows third parties to understand what devices and ecosystems are installed in a particular community and/or premise. Consumers use availability to better understand whether his/her system is available to be used for its intended purposes. For the electricity system, these data also allow for an understanding of what is activated/online during price response or load control events. Grid-responsiveness-related use cases such as those presented in mandatory demand-response will require availability data.

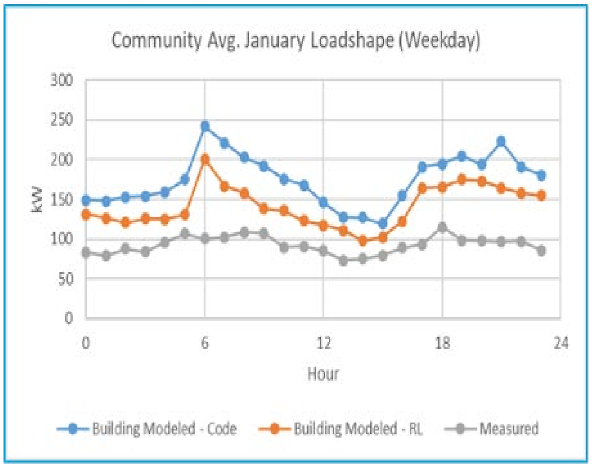
- **Device Performance Data:** Device performance data is defined as data parameters that indicate operational characteristics of a device or system. These can be estimated through the use of data parameters the system collects, calculated through using both known formulas and data parameters the system collects and/or measured directly through sensors and reported. Performance data can be anything from HVAC runtime collected from smart thermostats to the State of Charge (SoC) of energy storage systems to the state of operation of residential smart plug strips. Device performance data can serve as proxies for how often/when a device is being used. Consumers use this information to make decisions on how his/her system is performing. Analysis of this information by the energy system can also be used to provide third parties an understanding of the operational characteristics of a system during varying rates. See Figure E- 5: Example Mobile Application Showing (EPRI 2020b).

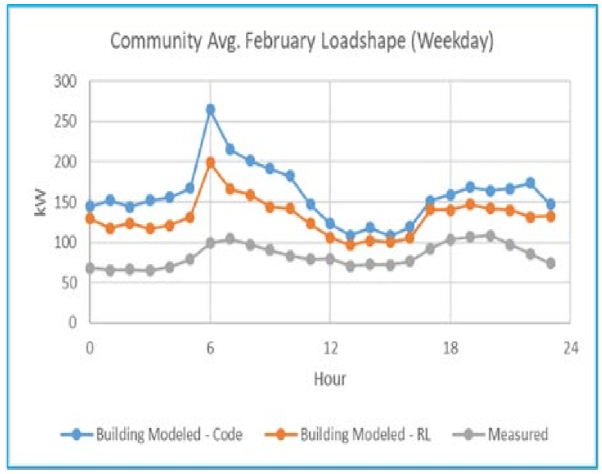
Figure E-5: Example Mobile Application Showing Device Performance Data



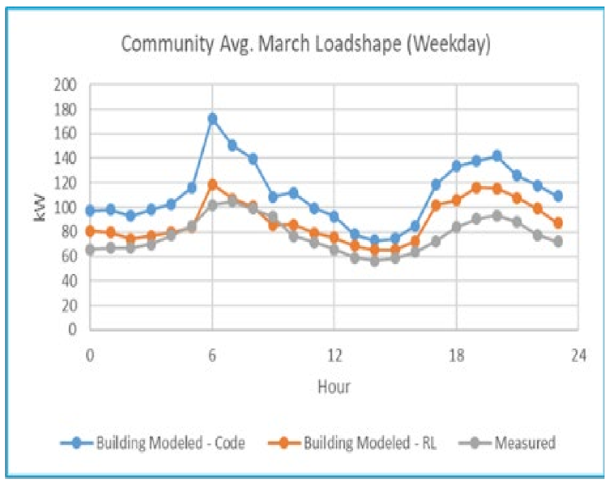
Source: EPRI 2021.

Figure E-6: Device Performance Data at the Community Scale





*(*Attempted to Scale February due to Considerable Data Loss)*

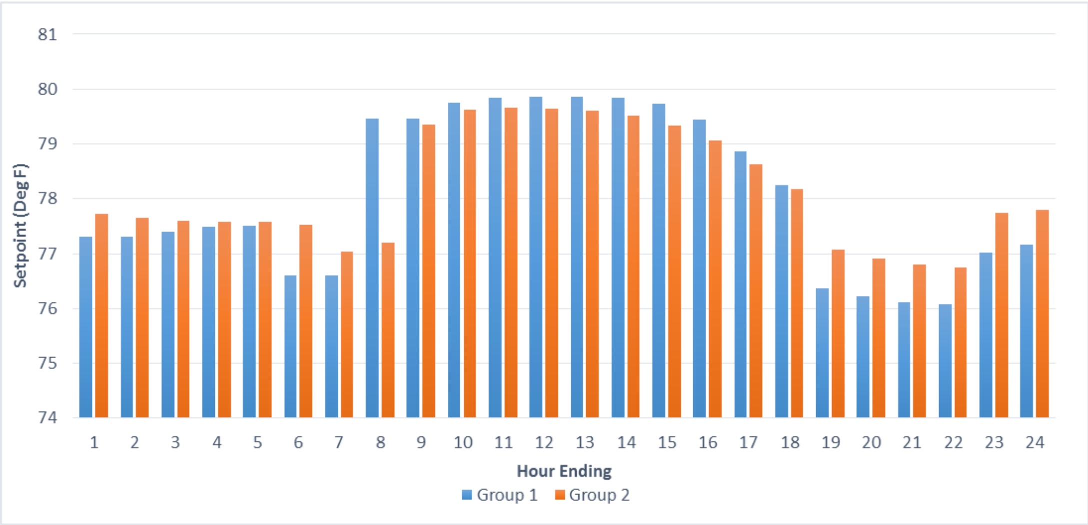


Source: EPRI and Southern Company 2020.

Note that Figure E-6 is a method for displaying device performance information (HVAC runtime) to a consumer and doing comparisons based on baseline performance. The intent is for that consumer to decide based on that performance information. Figure E-5: Example Mobile Application Showing is an aggregated set of data from a residential community compared to energy simulations made through building modeling software. The intent is to compare these results on load predictability by energy simulation tools for better energy system operations planning.

- **Customer Preference Data:** Customer preference data can be defined as data parameters that can indicate how a consumer will choose to use a system. Preference information is modes of operation of connected water heaters to temperature setpoints of thermostats to occupancy and schedule information of home security systems. Analysis of this data can serve as how/when a device is being used and can potentially be leveraged to indicate propensities to respond to a stimulus. See Figure E-7 (EPRI 2016c).

Figure E-7: Customer Preference Data at the Aggregate



Source: EPRI and Baltimore Gas and Electric 2016.

The data presented shows average hourly weekday setpoints for two smart thermostat product providers that are participating in a utility DSM program in the summertime. Note that one manufacturer has a much more aggressive setback[2] strategy that potentially resulted in less energy consumption for participants who chose those thermostats versus the other thermostats. In summary, preference information can be used where customer segmentation and targeting are important.

- **Environmental Data:** Environmental data are data parameters that monitor, collect and/or gather outdoor and/or indoor conditions in which the BTM DERs are commissioned. These data can include indoor temperature and outdoor temperature as well as solar irradiance. Analysis of this information can also be used to understand environmental changes caused by the system or environmental conditions in which a system is responding to.
- **Energy Data:** consists of measured, calculated or estimated energy data. These data can include energy values collected by circuit-level metering systems or estimated kilowatt-hour (kWh) values from disaggregated AMI meters. These data are typically used to support utility customer data to better attribute customer energy use.
- **Customer Data:** Consists of data that indicates an owner/user of a BTM DER. This data includes login information of the various users of a system and/or device serial numbers. These data streams are highly sensitive as they often times route to personally sensitive information. This information is usually important as it is used to tie information together from one data source to another. However, data governance rules are still evolving to ensure personally sensitive and identifiable information is not compromised.

[2] Setback strategy can be defined as reducing (in the wintertime) or increasing a thermostat's setpoint (in the summertime) to reduce HVAC energy consumption. This is sometimes tied to schedules or predicted or measured occupancy to attempt to ensure comfort conditions.

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Appendix F: Industry Tracking – Parallel Initiatives to the Open Demand Side Resource Integration Platform

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APPENDIX F: Industry Tracking – Parallel Initiatives to the Open Demand Side Resource Integration Platform

While this project was being completed, there have been several initiatives tracked by this project team looking integration of solar, storage and loads for residential load management. The following is not an exhaustive list, but a representation of various activities that were going on looking at scaling this at a utility-scale.

Grid Integrated Zero Net Energy Communities in Fontana, California

The project team worked alongside Meritage Homes and Southern California Edison to develop the first, Zero Net Energy Community to California Building Code (Title 24) in 2015. The community was built to better understand how a high penetration of distributed solar will have an impact on the distribution system. In addition, the community investigated how BTM DERs which included efficient electrification technologies such as connected HPWHs and smart thermostats can be used to better understand energy-impacting behaviors by consumers as well as be used as grid resources. First monitoring and then establishing tools and strategies for minimizing these impacts were some of the main lessons learned from this project (EPRI 2016a). Lessons learned when it comes to the value of device-level flexibility in high-penetration PV scenarios were one of the main outcomes of this project.

Hawaiian Electric Company (HECO) Solar, Storage, Water Heater and Thermostat Product Offer

As early as 2016, the state of Hawaii offered a combination of a solar PV panel installation, battery storage, a smart thermostat, a smart electric water heater and a local gateway to provide coordinated control of all these residential devices to maximize self-consumption (Wesoff 2016).[1] The state of Hawaii has a considerable portion of its residential customers with residential solar systems. Approximately 19 percent have a solar array installed in his/her home (SEPA 2019). Increased distributed solar production resulted in the need to discontinue Net Energy Metering (NEM). State of Hawaii rules in 2016 stated that a residential customer would no longer get credits for any excess distributed solar generation.

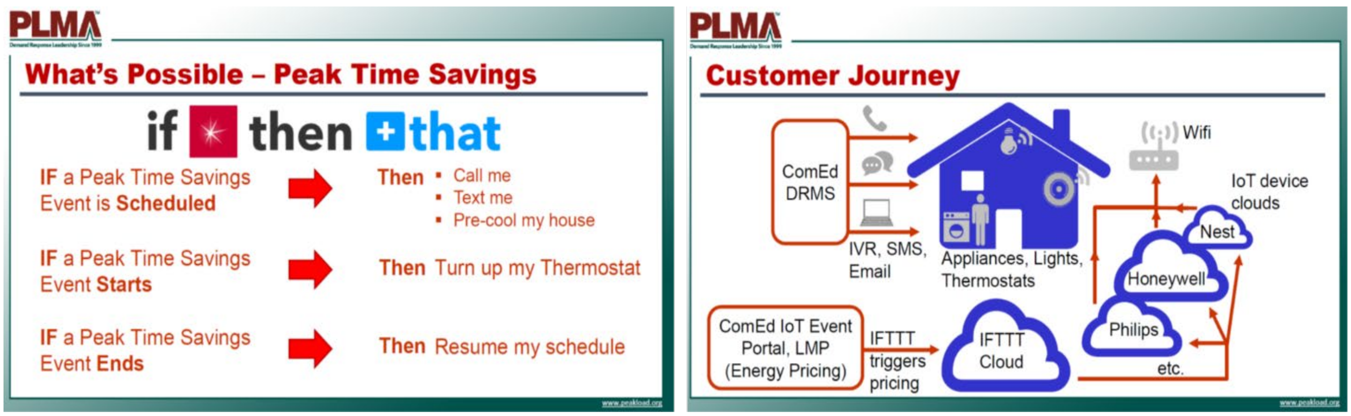
[1] Maximizing self-consumption can be defined as a residential premise using as much electricity as possible and minimizing the amount of electricity that is exported back to the electrical grid.

Commonwealth Edison (ComEd) Peak Time Savings Program

Since 2017, ComEd has piloted a Peak Time Savings Program and a Real-Time Pricing Pilot. This program helps ComEd customers reduce energy use during summer peak hours. There are two pilots and programs that the project team is aware of:

- If This Then That Pilot: If This Then That (IFTTT) is a web-based service that can be leveraged to create conditional statements that, when deemed true, result in an action that is programmed by and/or for a user (Figure F-1). In the case of ComEd, the conditional statement is ComEd's Peak Time Savings Event. See Kirchman 2018b.

Figure F-1: Commonwealth's Edison's Coordinated Load Management Using IFTTT (2017)



Source: Commonwealth Edison and Peak Load Management Alliance 2017.

Note that through the program, a customer can pre-define a list of actions before, during and after a Peak Time Savings Event.

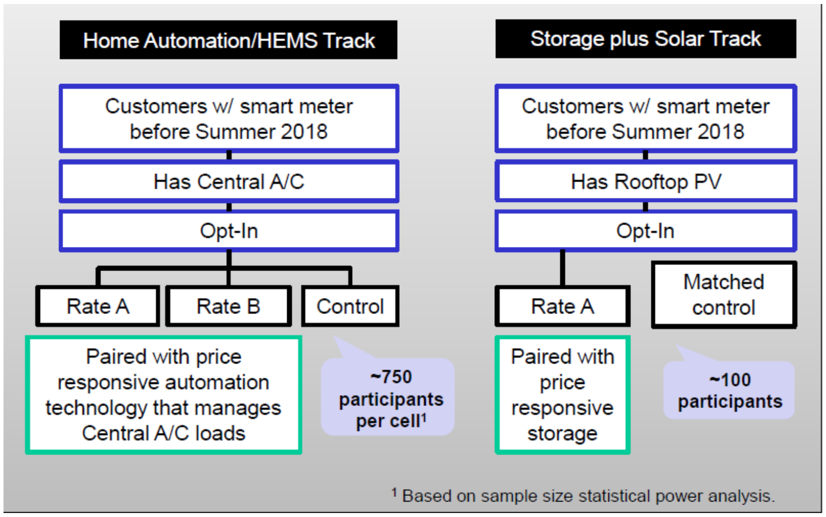
- Voice Assistants for Real-Time Energy Pricing: ComEd publishes real-time prices and offers real-time pricing programs (ComEd 2020). ComEd is investigating the use of voice assistants to help its customers be informed of his/her current energy price (Kirchman 2018b).

ConEdison (ConEd) Smart Rate Program

ConEd in New York is piloting a Smart Rate Pilot in which the state of New York is looking at evaluating customer responses to dynamic rate signals. This is in pairing with how BTM DERs such as smart thermostats and customer-sited battery energy storage can help its customers minimize their electricity bills. See Figure F-2 (Tsay 2018).

Unlike the HECO pilot effort, Figure F-2 shows that the Consolidated Edison pilot is divided into two tracks: home automation and solar plus storage. The work will focus on control of single loads, and HVAC using smart thermostats and storage respectively, to help respond to dynamic rates.

Figure F-2: Consolidated Edison Smart Rate Pilot



Source: Consolidated Edison 2017.

Arizona Public Service (APS) Behind the Meter DER Integration Pilot Project

In 2018, APS began a pilot project looking at load shifting, shaping, and shedding using a combination of BTM DERs. Through the use of a commercially available aggregator that has been serving as a DRMS/DERMS over the last few years, APS is looking at dynamically managing smart thermostats, connected water heaters, battery storage systems and smart inverters found in its residential customer base (St. John 2018).

Alabama Smart Neighborhood

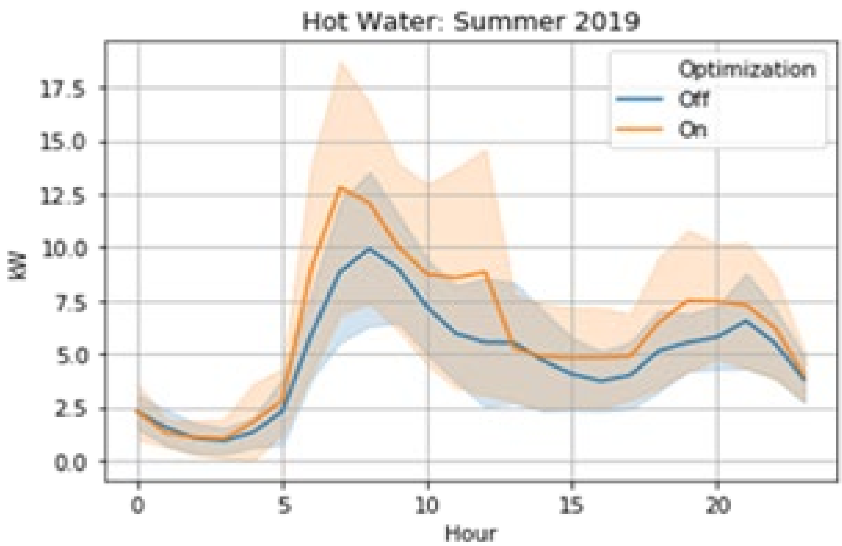
Starting in 2017, Alabama Power, Southern Company, EPRI, the United States Department of Energy (DOE) and Oak Ridge National Laboratory (ORNL) are investigating the demonstration of a 62 home residential community consisting of highly efficient homes that are 35 percent more efficient than Alabama code, combined with smart technology both using customer-sited smart technologies such as thermostats and connected water heaters, but also front of the meter resources connected to a microgrid controller (DOE 2018). See Figure F-3.

Figure F-3: Alabama Power Smart Neighborhood Project

Source: Alabama Power and Southern Company 2019.

The project team looked at various facets such as comparing community-level load data to building energy simulations, performance of advanced efficient electrification technologies and how these technologies, buildings and communities can be used as a grid resource. See Figure F-4 for an example analysis of efficient electrification technologies (HPWHs) being used as a grid resource.

Figure F-4: Evaluation of Efficient Electrification Technologies as a Grid Resource



Source: Southern Company and EPRI 2020.

The project team has wrapped up its first two-year study of the community (EPRI 2020d).

Georgia Smart Neighborhood

In the Summer of 2020, many of the same people who worked on the Alabama Smart Neighborhood investigated how buildings can be used as grid resources through the use of the Georgia Smart Neighborhood. Unlike the Alabama Smart Neighborhood, all technologies in the Smart Neighborhood are customer-sited – solar, battery storage, connected water heaters and smart thermostats.

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix G: Controls and Data Made Available from Behind-the-Meter Distributed Energy Resources

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APPENDIX G: Controls and Data Made Available from Behind-the-Meter Distributed Energy Resources

This appendix provides additional detail on how controls and data were made available by BTM DERs at the time this report was written. High-level results from the assessment of device-level data and controls are summarized below (Clarin 2018).

1. Method of data reporting is not uniform from one product provider to another: Analysis of data associated with smart thermostats, one of the more mature BTM DERs as it pertains to data exchanges from connected devices, identifies various levels of data availability and methods of reporting. This is most likely a result of various factors including data storage, perceived use cases for data and existing infrastructure of current product and service providers.
2. Data specifications are available for certain BTM DERs and certain use cases: As previously mentioned, smart thermostats were the first set of connected devices that sparked interest from utility programs and associated standards organizations and research institutions. The interest is a result of harmonizing the need to conduct continuous evaluations of quantifiable and verifiable energy impacts while accounting for rapid technology change. As a result, organizations such as the United States Environmental Protection Agency (U.S. EPA), the Consortium of Energy Efficiency (CEE) and the Electric Power Research Institute (EPRI) have developed smart thermostat data specifications to facilitate developing frameworks on how data is collected from manufacturers and service providers for Demand-Side Management (DSM) needs.
3. Tools for data analysis and platforms enabling controls of BTM DERs are appearing in the market: One of the current technology gaps is the lack of transparent tools that quantify energy impacts associated with connected device data. Recently, open-source tools have been made available; an example is Vermont Energy Investment Cooperative’s (VEIC)’s Smart Thermostat Analytics Toolkit (STAT). Several BTM DER aggregation platforms are expanding their reach into not only smart thermostats, but other DERs as well.
4. Data specifications still need to be validated for effectiveness: While some use cases are more mature than others, the valuation of data from BTM DERs is still in its nascent stages. It is important to continually validate the effectiveness of each data specification as more use cases are identified and more devices are enabled by these systems. It is important to also validate these specifications when compared to other methods such as completing the same use cases using only AMI data or qualitative analyses via surveys.

5. Data Specifications are Needed for Other Customer-Sited BTM DERs. Smart thermostats were the first set of customer-procured connected devices that have the potential to be leveraged as both customer engagement tools as well as grid resources. As other devices and systems continue to follow suit (such as water heaters and EVs), it will be important to continue to develop data specifications for other BTM DERs to understand how residential homeowners and occupants are using energy associated with systems monitored and/or controlled by connected devices - an area of rapid technology change. For example, building codes set forth by the California Energy Commission (Title 24) are looking at including reported data from the connected HPWH as part of its Joint-Appendix (JA) 13 specification.
6. Data is typically made available by third parties through flat file transfers or APIs: In addition to data made available through dashboards provided to third parties, the most common methods of data transfer are either flat file transfer through some form of Secure File Transfer Protocol (SFTP) or via API commands through RESTful commands to a particular product provider's server. API commands are typically attributed to an infrastructure that needs to support continuous product development.
7. Training data sets and other tools are still needed to validate Control Functions: Valuation of control of BTM DERs is still in the nascent stages. It is important to continue to collect operational data sets and develop other tools to validate control functions.

The following section goes into additional detail about specific BTM DERs.

Circuit-Level Metering and Smart Panels

Circuit-Level or data monitoring focused ecosystems can be divided into two subcategories:

- **Non-Intrusive Load Monitoring (NILMs):** Refers to measuring electric power or energy at the whole premises to estimate energy use attributed to individual end-loads.
- **High-Resolution Data Monitoring Equipment:** Typically, "customer data" as defined by the utility constitutes either quantitative data identified by AMI infrastructure or qualitative data obtained through customer surveys. This report will differentiate this subcategory from NILMs as circuit-level monitoring at a higher level of detail (monitoring at the circuit level versus the home level). Typically, this is done by circuit breaker level metering.
- **Smart Panels and Circuit Breakers:** Emerging systems that enable embedded data collection and controllability of loads.

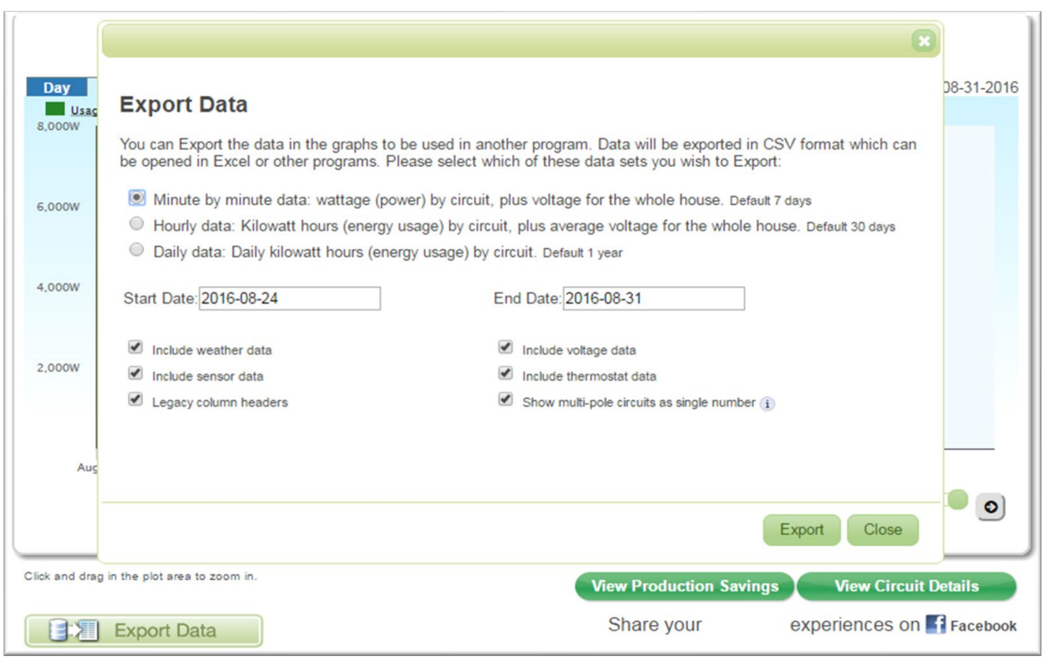
See Figure G-1 for the circuit-level metering system installed.

Figure G-1: Evaluation of Efficient Electrification Technologies as a Grid Resource

Source: EPRI

The project team's experience is that most circuit-level monitoring providers allow access to its API or data to third parties in some form of autonomous basis or provided through SFTP arrangements. When using APIs, the data API is through RESTful commands to the circuit-level monitoring provider's current server. In addition to autonomous methodologies, circuit-level monitoring providers also allow data collection via reporting functions as shown in Figure G-2.

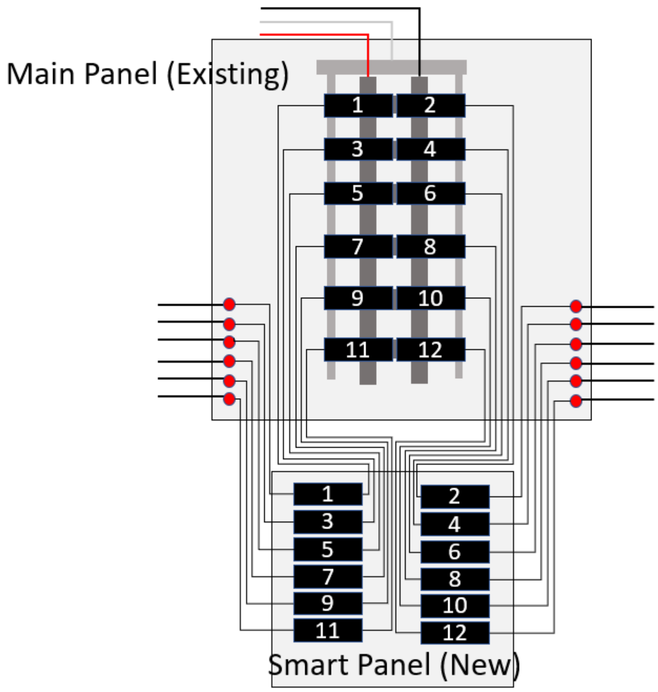
Figure G-2: Web Tools for Data Export of Data from Circuit-Level Metering



Source: Powerwise Systems 2016.

Evaluation of smart panels began as an exploration of solutions to enable electrification in multi-family buildings. Recognizing the available scheduling and load shedding capabilities of the chosen smart panel, along with an available product API, integration into the DSRIP platform was further explored. See Figure G-3.

Figure G-3: Example Smart Panel Layout



Source: EPRI

Smart panels and intelligent circuit breakers are a potential solution to widespread controllability and building flexibility but have yet to be proven from both a cost-effectiveness and technological capability perspective. The technical capabilities exist, but the negative impact on occupant behavior due to simple On/Off control at a circuit breaker level still needs to be understood at scale.

Smart Thermostats

One of the first connected devices of great interest to energy companies is the use of smart thermostats as a demand-side management tool. One opportunity sometimes lost in this discussion is the potential to collect data to better understand customer preference and/or system performance at a more detailed level.

Before and during this project, the project team worked with many thermostat providers in which these providers granted API access to the data and/or some form of aggregate reporting tool as discussed with circuit-level monitoring infrastructure. It is important to note that based on previous experience of the project team, we can potentially see a scenario where certain data parameters collected as part of this project were only available due to agreements between the thermostat provider and the project team for the sake of this project. This was based on previous experience with these providers. See Table G-1.

Table G-1: Data Availability Summary from 5 Smart Thermostat Product and Service Providers

	Environmental Data	Customer Preference Data	Energy Data	Resolution Collected	Resolution Reported	Method of Data Transfer
Product Provider 1	Indoor Temperature Humidity Outdoor Temperature Windspeed	Mode of Operation Indoor Temperature Setpoint	HVAC Runtime DR Event Information	1 second	5 minutes	APIs and reports
Product Provider 2	Indoor Temperature Outdoor Temperature	User Interactions Indoor Temperature Setpoint	HVAC Runtime	1 minute	60 minutes	Reports to Utility
Product Provider 3	Indoor Temperature Outdoor Temperature (certain models)	Mode of Operation Indoor Temperature Setpoint	HVAC Runtime DR Event Information	N/A (event driven)	Event Driven	Reports through DRMS or Server-Server
Product Provider 4	Indoor Temperature Outdoor Temperature (Hourly)	Indoor Temperature Setpoint	HVAC Runtime Estimated Energy Used	1 minute	15 minutes	Reports to Utility and Reports through DRMS
Product Provider 5 (Option 1)	Indoor Temperature	Temperature Setpoint User Interactions	HVAC Type HVAC Runtime		2 hours	Reports to Utility
Product Provider 5 (Option 2)[5]	Indoor Temperature	Temperature Setpoint	HVAC Runtime		15 minutes (Aggregate Only)	Reports to Utility

Source: EPRI

[5] This option only provides aggregate results and not at the thermostat level.

To begin the conversation of data normalization, tools such as data specifications can be used to help provide minimal viable products as they pertain to how one can leverage data parameters for specific use cases. Note that one can see how data parameters and data resolution will vary based on the use case. A sample data specification used to help quantify and attribute energy reduction benefits for smart thermostats is summarized in Table G-2 and Table G-3. Note that both tables were used to discuss both the parameter as well as the rationale of the potential value of the data parameter.

Table G-2: Meta Data Potentially Available to Enable Smart Thermostat Orchestration

	Thermostat Specifier	Reason
1	Unique Thermostat ID # or Device Identifier	Use as a cross-reference for communicating between vendor, utility, and end user.
2	Vendor Description	To identify the vendor that supplied and is managing the thermostat.
3	Thermostat Description	To determine what type and model of thermostat is installed.
4	Date Thermostat Installed	To establish a date that savings began and to parse baseline data.
5	Date Thermostat Removed	To establish a date when the savings ended or changed.
6	Software Version	Needed to track performance across software updates.
7	Zip Code (5 digits)	1) Use to look up local hourly outdoor temperature; 2) to locate where the thermostat is installed; 3) to group thermostats; 4) to cross reference to climate zones and utility service areas.
8	System Ability to Heat	Needed to categorize for heating and/or cooling preface evaluation.
9	Reported Heating System Type (text)	Useful for performance categorization. (Expectation is that this is user reported and not always available or accurate.)
10	Reported Number of heating stages	Need to know for better performance characterization
11	System Ability to Cool	Needed to categorize for heating and/or cooling performance evaluation.
12	Reported Cooling System Type (text)	Useful for performance categorization. (Expectation is that this is user reported and not always available or accurate.)
13	Reported number of cooling stages	Need to know for better performance characterization

Source: EPRI

While Table G-2 details meta-information, Table G-3 details the operational parameters of the smart thermostat.

Table G-3: Operational Data from Smart Thermostat to Potentially Energy Optimization and Orchestration

Data Stream Parameter	Why required
Unique Thermostat ID # or Device Identifier	A unique alpha-numeric identifier that links data collected from a specific connected device.
Date and Time	Date and time in which thermostat-level data values are collected.
Connectivity	Status of thermostat connection during the data collection period.
Outdoor Temperature (F or C)	Outdoor environmental temperature collected via third-party weather station data or an external temperature sensor.
Indoor Temperature (F or C)	Average or current indoor temperature collected
Indoor Setpoint Temperature (F or C)	Proxy for customer climate preference.
Cooling Run time (seconds)	Energy performance parameter used attributed to the space cooling.
Heating Run Time (seconds)	Energy performance parameter used attributed to space heating.
Auxiliary Heat Runtime (seconds)	Energy performance Parameter to the electric resistive element
Emergency Heat Runtime (seconds)	Energy performance Parameter to the emergency heating element
Outdoor Relative Humidity	Outdoor relative humidity. Especially applicable in humid climates with an interest in cooling
Relative Humidity Setpoint (when available)	Additional proxy for customer preference. Pertinent in applicable climates and in thermostats where this feature is available.
Mode of Operation	Current thermostat setting. Includes HEAT, COOL, AUTO, and OFF.
Current Schedule	Current schedule which customer is following. Can include HOLD, VACATION, AWAY, FOLLOWING SCHEDULE, OFF.
Targeted Indoor Setpoint (F or C)	In instances where an intelligent algorithm causes thermostat indoor temperature setpoint to vary from the customer-inputted temperature setpoint

Source: EPRI

Variable Speed Heating, Ventilation, and Air Conditioning Systems

Variable-speed HVAC systems offer inherent energy efficiency advantages over conventional single-speed HVAC systems. The ability to regulate zone-level temperatures without requiring the full capacity of the HVAC system to overshoot the setpoints provides for more efficiency.

However, in this project, the project team investigated data collection from one of the manufacturers of variable capacity HVAC systems that do provide data to third parties. The team developed a data model for ingesting operating data from both the indoor and outdoor units of the HVAC system. Details of the data specifications are provided in Table G-4.

Table G-4: Data Model Created for Variable Speed Heating, Ventilation, and Air Conditioning Systems

Parameter – Definition	Parameter – Definition
Blower RPM – Furnace/Air Handler speed in RPM.	Components – Detachable components of the HVAC system, for example, ventilator, and humidifier.
Compressor RPM – Compressor speed of the variable speed HVAC system in RPM.	Component Status – On/Off status
Discharge Temp – The compressor's discharge temperature.	Entered Ref Temp – Temperature of air entering the cooling or heating coil.
Expansion Valve Position – Position (in %) of the expansion valve.	Hold Enabled – Is the thermostat on a hold mode?
Indoor Unit CFM – Indoor unit airflow measured in CFM.	Is Connected – is the thermostat connected to WiFi?
Is Curtail – is the HVAC system currently responding to a DR event?	Leaving Air Temp – Temperature of air leaving the Air handler
Line voltage – the voltage at which the HVAC system is operating.	Mode – the HVAC mode
Operating Mode – the heating/cooling mode in which the HVAC is currently operating.	Operating Status – A number between 0-100 representing the operating status of the HVAC system
Outdoor Air Temp – Ambient outdoor temperature.	Outdoor Coil Temp – Coil temperature of the outdoor unit.
Static Pressure – pressure representing the resistance to airflow in the heating/cooling system and ducts.	Suction Pressure – Intake pressure of the system generated by the compressor.
Suction Superheat – the superheat (temperature beyond the boiling point of the refrigerant) in the evaporator.	Suction Temp – temperature of suction at the evaporator coil.
Zone Cool Setpoint – cooling setpoint at the zone.	Zone Damper position – Position of the damper (in %) for a specific zone.

Parameter – Definition	Parameter – Definition
Zone Fan Speed – fan speed at the zone.	Zone Fan Status – On/off Status of the fan at the zone.
Zone Room Temperature – Room Temperature at the zone	Zone Room Humidity – Room Humidity at the zone.

Source: EPRI

Connected Heat Pump Water Heaters (Unitary Systems)

With efficient electrification to enable decarbonization targets now of interest, there is increased interest in the opportunity to: (1) electrify water heating technology and (2) leverage thermal storage capabilities of advanced, connected water heaters. Because of this, connected heat pump water heaters were investigated for their ability to collect data for both understanding how electrification of water heating will impact the electric grid and (2) how electric heat pump water heaters can be used as a grid resource.

In this project, the project team investigated data collection from primarily 2 water heater manufacturers. Data collection of each manufacturer has some similarities, but each approaches data collection and control from different standards perspectives. Details of a data specification for connected Heat Pump Water Heaters are provided in Table G-5.

Table G-5: Data Availability Varies by Product Provider

	Environmental Data	Customer Preference Data	Energy Data	Resolution Collected	Resolution Reported	Data Transfer Method
Product Provider 1	Tank Top Temp Tank Bottom Temp Ambient Temp	Mode of Operation Temperature Setpoint Min and Max Setpoints	Instantaneous power consumed	5 minutes	5 minutes	APIs
Product Provider 2	Tank temperature	Setpoint Mode of operation Min and Max setpoints	Energy consumed Thermal capacity	1 minute	5 minutes & On-Demand (Event driven)	SFTP

Source: EPRI

It is important to note the differences in the approaches between the two manufacturers, with potentially similar results as they pertain to data collection. Note that manufacturer 1 is primarily focused on providing sensor data while manufacturer 2 is providing calculated data assumed from a combination of sensor data as well as assumptions based on the operational state.

Residential Energy Storage

Residential energy storage system manufacturers offer a variety of access levels and operational data to third parties. As a starting point, the project team developed data acquisition and data model development from a manufacturer of residential energy storage systems. Details of the Residential Energy Storage data model are shown in Table G-6. Note that this is not a data specification, but an assessment of feasibility based on project team experience.

Table G-6: Normalized Data Model for Residential Energy Storage Systems

Parameter – Definition	Parameter – Definition
Consumption: Total Power consumed by residential loads.	Production: PV production at the residential level.
Grid Feed: Total power fed in from or out to the grid.	Inverter AC Power: Total power at the inverter.
Relative SOC: Relative State of Charge	User SOC: User State of Charge. User SOC is Relative SOC minus the portion required by code to be used for resiliency during outages.
AC Frequency: Frequency of the AC power.	AC Voltage: Line voltage of the AC power.
Battery Voltage: DC Voltage at the battery.	

Source: EPRI

Electric Vehicles

The project team worked with 3rd party electric vehicle charge optimization platforms to develop a data model for electric vehicles and set up a data acquisition mechanism. Even though the project team has had extensive experience working with V2G type applications, getting operating data from EV OEMs required working one-on-one with each OEM and is therefore inefficient. The team had the most success working with a 3rd party charge optimization application discussed later in this chapter. From this platform, the project team developed a data model shown in Table G-7.

Table G-7: Normalized Data Model Used by Open Demand Side Resource Integration Platform for Electric Vehicle Data

Parameter – Definition	Parameter – Definition
Battery Capacity and Range: Configured battery capacity and range.	State of Charge: Percentage state of charge.
Desired State of Charge: Configured desired state of charge for a given charging event.	Charging state: Enumeration corresponding to the charging event.
Latitude: Latitude of the charging location.	Longitude: Longitude of charging location.
Charge Pilot Current: Pilot current configured to be used for the charging event.	Charge Pilot Actual: The actual instantaneous current used in the charging event.

Parameter – Definition	Parameter – Definition
Charger Voltage: AC Voltage measured at the charger.	Charger Power: Power measured at the Charger.
Time Until Full Charge: Time taken by the battery to charge up to the "desired state".	Charger Phase: Enumeration representing the phase of the charging event.
Super Charger: Boolean representing if the charging is occurring at a supercharger location (or at a DC fast charging location)	Scheduled Charging Pending: Pending charge event based on schedule.
Scheduled Charge Start Time: Start Time of a scheduled charge event.	Speed: Vehicle speed when vehicle is in motion.
Odometer: Odometer reading of the vehicle.	Inside Temperature: Temperature inside the electric vehicle.
Outside temperature: Outdoor temperature (outside the electric vehicle)	Smart Preconditioning Enabled: Is the vehicle's smart pre-conditioning enabled?

Source: EPRI

The project team found an alternative approach to getting data from electric vehicles was to work with EV fleet-level aggregators. A comparison of data models from two different aggregators shows the wide variability in the availability of data. This is summarized in Table G-8.

Table G-8: Comparison of Electric Vehicle Data Specifications

	Environmental Data	Customer Preference Data	Energy Data	Resolution Collected	Resolution Reported	#
EV Aggregator 1	Indoor Temp Outdoor Temp Odometer Lat/Long	Desired state of charge Charging Schedule	Charge Power, Charge Current, Charge Voltage, Super/DC Fast charger present, Battery State of Charge	1-minute	15-minute	APIs
Product Provider 2	N/A	N/A	Charge Energy measured via AMI	15-minute	15-minute	File Transfer

Source: EPRI

Other Smart Residential Systems

Other smart residential systems were investigated for data collection feasibility.

- **Solar Inverters/Smart Inverters:** Although it is important to note that data on PV generation was deemed retrievable, it was noted that the information (solar output), was redundant as this information could be collected from other sources. Therefore, as the focus of creating a data warehouse is data aggregation and normalization, data collected from smart inverters were not included in the analysis. Additionally, none of the main use cases in this project required specifics as it pertains to data parameters provided by the solar inverter only.

- **Voice Assistants:** One main point of interest for many third parties is lowering transaction costs through some form of centralized point of coordinated control and data aggregation. Since 2015, with large market players such as Google and Amazon interested in the market, many of the connected devices discussed in this list are or claim to work w/ Amazon Echo and/or Google Home. Here lies an opportunity to leverage a potentially centralized point of data aggregation and normalization. However, based on the research completed during this project, it was found quicker to access device-level data via specific device APIs associated with each project versus leveraging voice assistant platforms as a single point of aggregation. Voice assistants were instead used as a point of: (1) device integration, and (2) consumer messaging throughout the project.
- **Smart Hubs:** Another point of potential coordinated control as progressive homebuilders have an interest in leveraging smart hub products to enable smart home functionality in new home developments. When this report was written, the largest player in this space was SmartThings, a Samsung product. The foundation of this product is similar to that of voice assistants where products like SmartThings tout compatible products in the order of over 10,000 connected devices. Although promising for energy optimization and grid responsiveness, hub-based ecosystems have not developed in these areas as the core function enabled by these providers is the orchestration and control of multiple connected devices within a premise. In addition, many residential IoT providers have shown interest or have already begun embedding hub-based functionality within other connected devices. At the time this report was written, it did not seem beneficial as well as feasible to collect data from smart hub providers. In addition, this data was identified as redundant to much of the data collected from the connected devices discussed above. As with the voice assistant platform, it was deemed not practical to investigate smart hub data acquisition functionality as part of this project.

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix H: Open Demand Side Resource Integration Platform Lessons Learned During Field Demonstrations

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APPENDIX H: Open Demand Side Resource Integration Platform Lessons Learned During Field Demonstrations

This appendix details the demonstration projects leveraging OpenDSRIP as a tool to understand how BTM DERs today can provide coordinated load management for dynamic energy rate signaling. These summaries presented in Appendix H detail the results presented in Chapter 3.

Originally Intended Demonstration Community in Southern California

The project team had originally expected to use a ZNE community in Southern California in Fontana as the field trial site. The site was a community built in 2015-2016 and comprised of 20 ZNE homes equipped with efficient electrification technologies (heat pump and connected HPWHs) and smart home (circuit level metering and smart thermostats) technologies. However, the project team did not pursue additional work on this site. It is important to understand the lessons learned from site assessment as these are crucial factors in assessing both the scalability and the persistence of coordinated load management of customer-sited DERs for TOU management. Main lessons learned were:

- The smart thermostat installed in that community did provide opportunities for coordinated control. However, access to the thermostat controls was challenging as it could potentially remove a customer from their ability to sign up for HVAC maintenance programs provided by the heat pump manufacturer.
- Connected HPWHs were difficult to commission. At the time of the pilot (2016) the communication modules provided challenges due to firmware/aggregator challenges which resulted in only 2 of 20 connected HPWHs being able to provide load management.
- Nine of the twenty homes had residential energy storage systems. It was determined that although the storage systems did have controllability by third parties, there were limitations in their ability to provide coordinated control with other systems within the ZNE community. In addition, there would have to have been a firmware upgrade to the local battery energy management system.

With this as well as other considerations, the project team conducted field demonstrations and technology development at the project sites listed below.

Aggregation and Orchestration in a Clovis Zero-Net-Energy Community

The project team collaborated closely with a local homebuilder in the Central Valley in developing a community of zero-net energy homes in Clovis, California (CA CZ3). The community comprising of 36 high-efficiency (HERS 57) single-family homes with floorplans ranging from 3 to 6 bedrooms and 1900 to 3530 sq. ft. These homes were designed with efficient electrification technologies such as two-stage high-efficiency HVAC systems, connected HPWHs, option to purchase residential energy storage systems, EV charger-ready and a solar array to offset additional electricity to meet California ZNE requirements. Circuit-level energy monitors were installed to measure and disaggregate loads.

The overall goal of this demonstration and the associated site was: (1) What is the feasibility of aggregation of tiered coordinated control strategies of BTM DERs using an open-sourced residential orchestration of devices today for load management using rate signaling? And, (2) What are the opportunities and barriers to scaling orchestration for providing utility-grade grid and energy services in a fairly fragmented DER market?

The technologies deployed are summarized in Table H-1. It is important to note that the project team did not prescribe these technologies but worked with the homebuilder and its trades to better understand what a "smart home" offering looks like to that homebuilder. As a result, a combination of distributed generation, smart home and efficient electrification technologies were deployed.

Table H-1: Technologies Installed and/or Evaluated as Part of Clovis Zero Net Energy Site

Technology	Purpose	Notes
Circuit level metering	Collection of disaggregated load data at a circuit-breaker level to help attribute overall house impacts to specific end-uses within a home.	Originally intended circuit-level metering provider changed its technology making the original data collection pathway obsolete. In addition, the project found infrastructure barriers to enabling data collection at scale with the original circuit-level metering provider. A new circuit-level metering provider was used as a result of this.
Connected HPWHs	Efficient electrification technology as well as investigate thermal storage/TOU management potential.	
HVAC/Heat Pump Technology	Efficient electrification technology as well as investigating thermal storage/TOU management potential through smart thermostats.	In the middle of home construction, the homebuilder was notified of HVAC availability shortage of originally intended two-speed HVAC systems and offered variable capacity HVAC

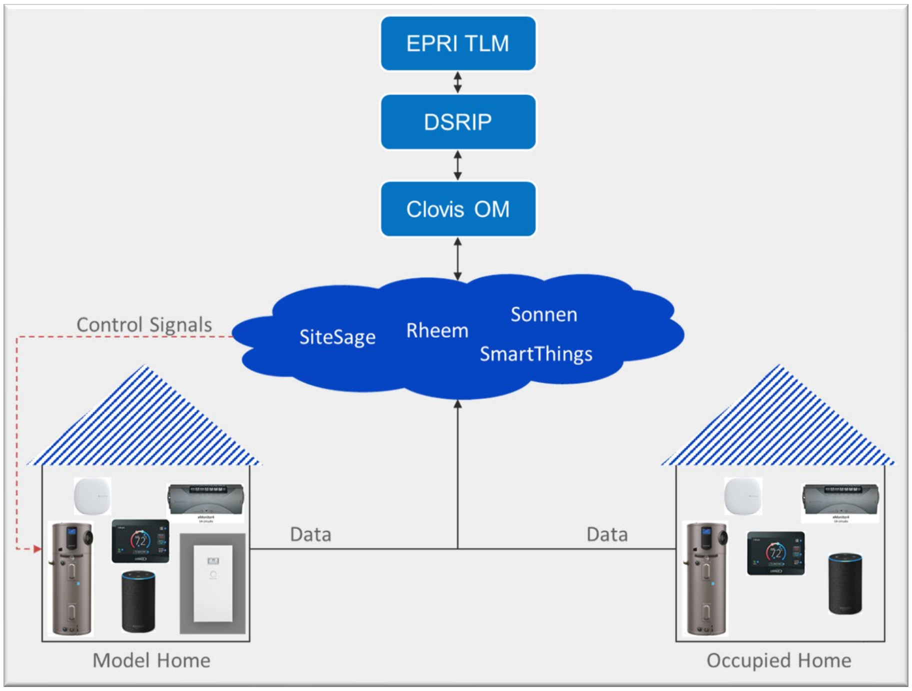
Technology	Purpose	Notes
		systems from the same manufacturer. However, variable-speed HVAC systems usually come with proprietary HVAC controllers with limited functionality to enable coordinated load management from third parties at the time that this report was written.
Residential Energy Storage System	Optional community technology is used to provide TOU rate management as well as backup power for the customer.	Homeowners were given the option of buying energy storage systems from two residential energy storage providers.
Residential PV Array	Offset additional estimated energy consumption to meet ZNE requirements.	
Smart Hub and Smart Plugs	Enabling home automation. Establish the feasibility of controllability of smart home technologies (for example smart plugs and lights) using commercially available smart hubs (for example SmartThings).	
Voice Assistants	Enabling home automation and rate messaging.	

Source: EPRI

Demonstration Design

The homebuilder, wary of a full-scale demonstration involving "control" of homeowner technologies, requested that the project team conduct "proof-of-concept" style testing at the community model homes before any scaled field placement was completed. The model home enabled a laboratory environment as it contained all of the technologies that were installed in the community. In addition, unlike the community, a third-party controllable smart thermostat was also available to test the feasibility of home orchestration involving HVAC systems (Figure H-1).

Figure H-1: Open Demand Side Resource Integration Platform Architecture in Clovis Zero Net Energy Community

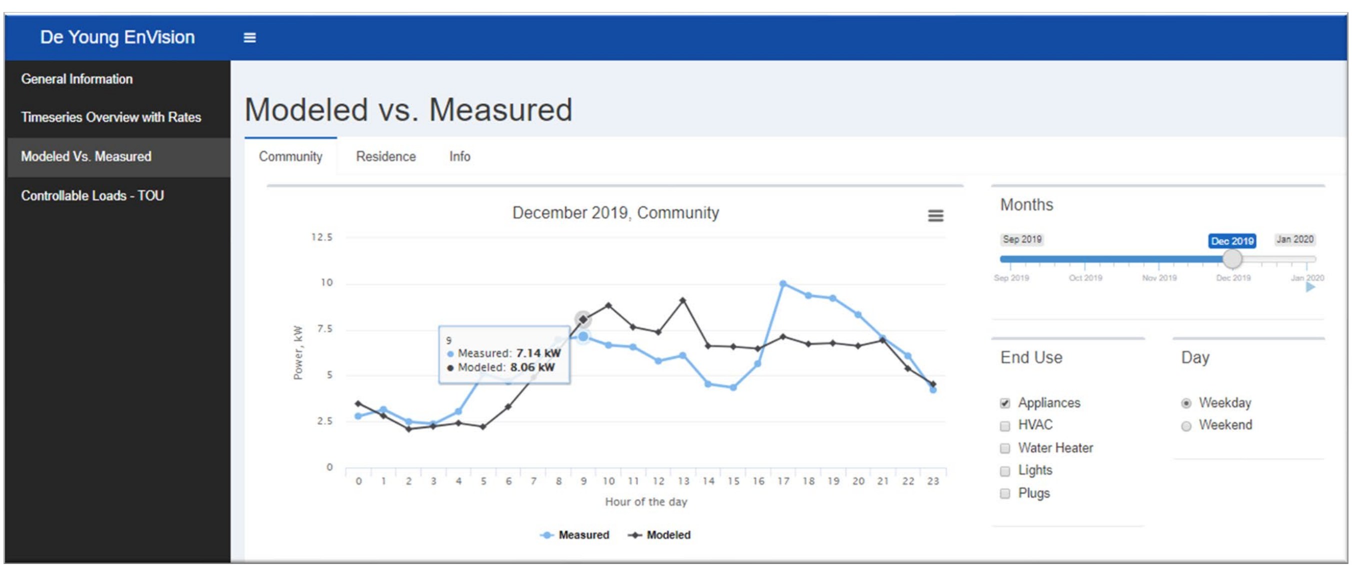


Source: EPRI

Project Results

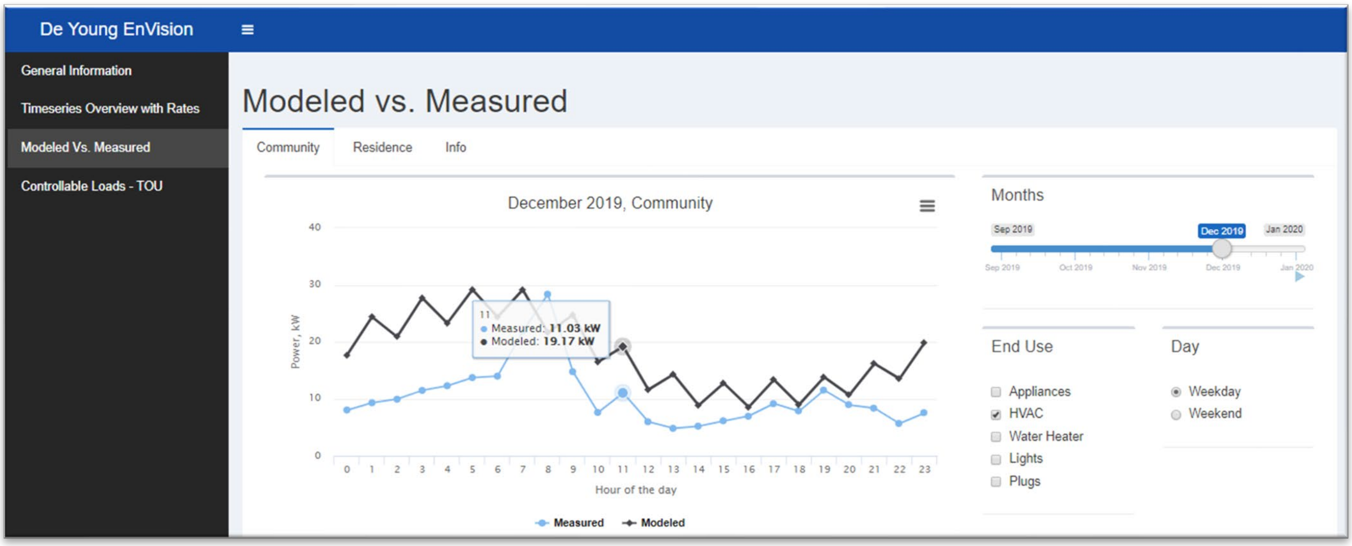
High-level project results are summarized in Chapter 3. However, the project team was able to additionally glean information from the project site. See Figure H-2 through Figure H-6.

Figure H-2: Comparison of Measured Appliance Loads to Energy Simulations for December 2019



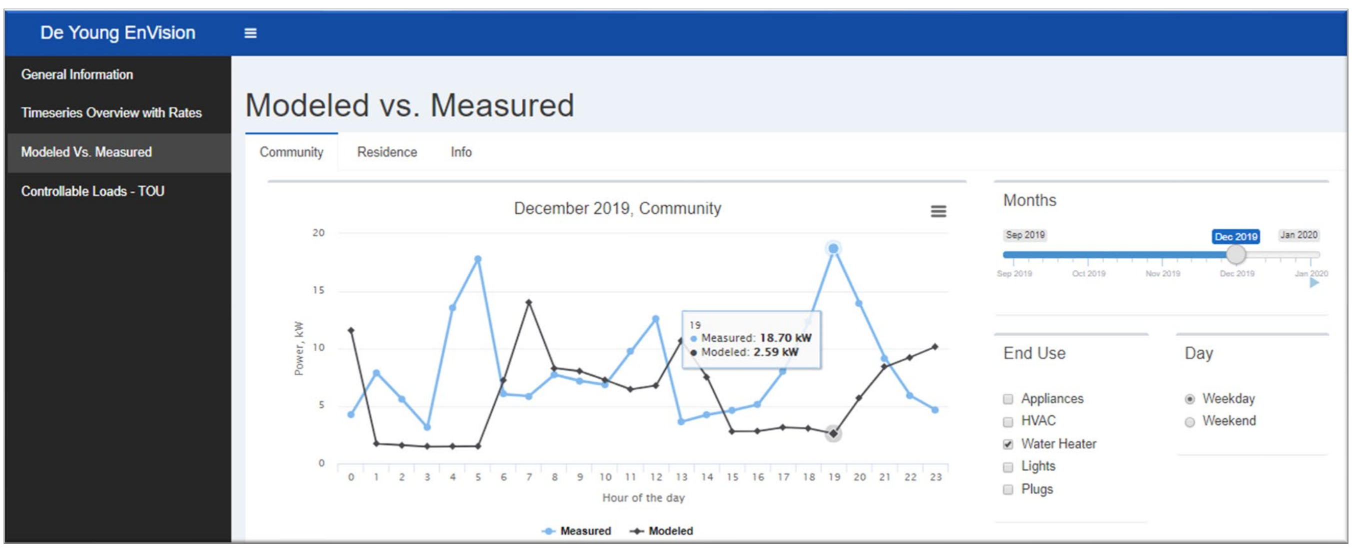
Source: EPRI

Figure H-3: Comparison of Measured Heating, Ventilation, and Air Conditioning Load to Energy Simulations for December 2019



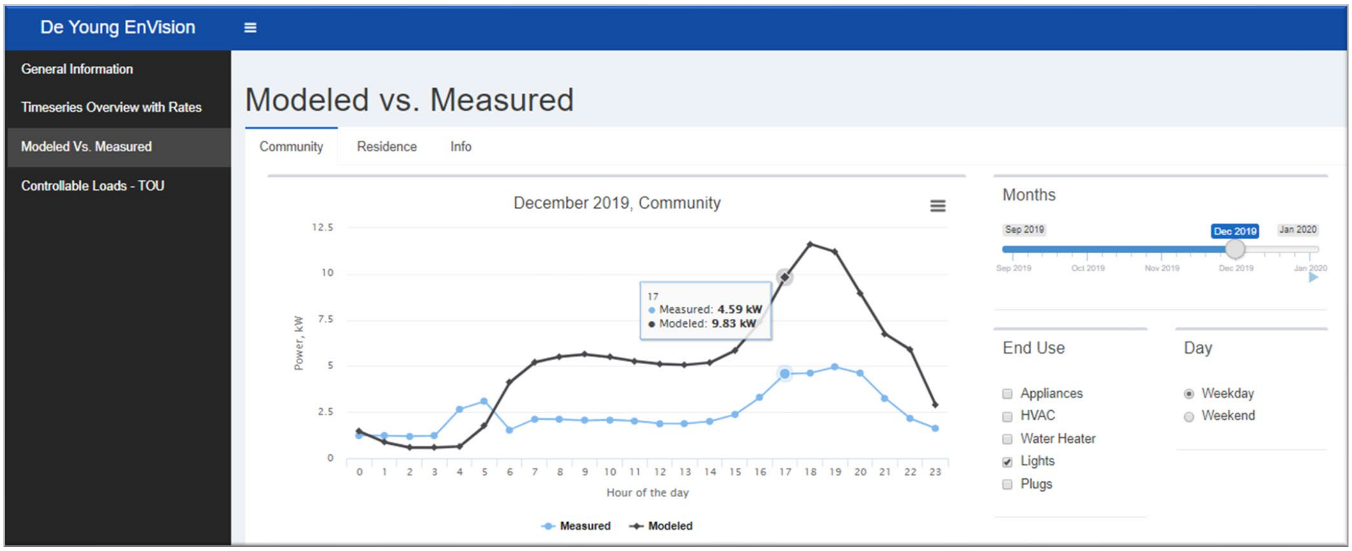
Source: EPRI

Figure H-4: Comparison of Measured Water Heater Load to Energy Simulations for December 2019



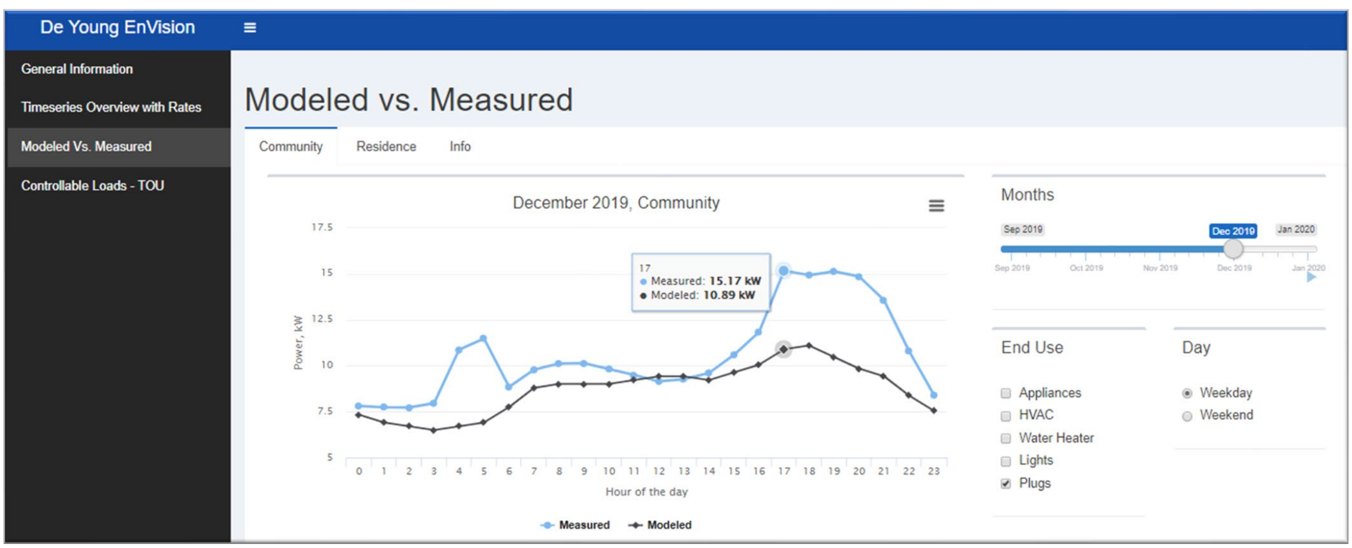
Source: EPRI

Figure H-5: Comparison of Measured Lighting Load to Energy Simulations for December 2019



Source: EPRI

Figure H-6: Comparison of Measured Plug Loads to Energy Simulations for December 2019



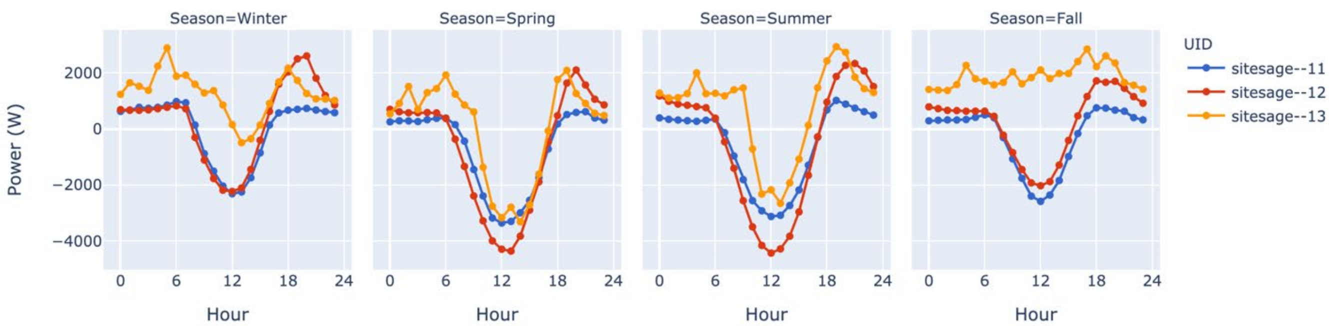
Source: EPRI

Next Steps

The project team continues to work on this project through continuous data collection to better understand how TOU rates and efficient electrification enable building decarbonization. The project also continues to work with the HVAC manufacturer to potentially receive third-party access to enable coordinated control of variable-speed HVAC systems. Finally, the project team continues to work with this homebuilder in developing and testing orchestration routines of the BTM DERs installed in this community.

Overall net-mains load shapes of the “efficient heat pump” user (blue), the “mid-level” user (red), and the “high demand” user (yellow). Note that the solar PV and battery data is missing from the calculation of net-mains for the high-demand user in the fall and part of winter 2020 (Figure H-7).

Figure H-7: Seasonal Load Shapes for Three Homes in Clovis Community in 2020

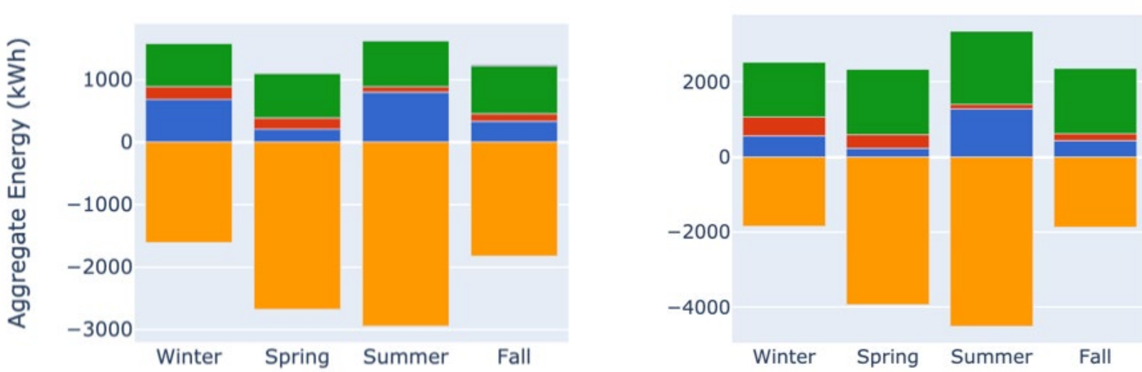


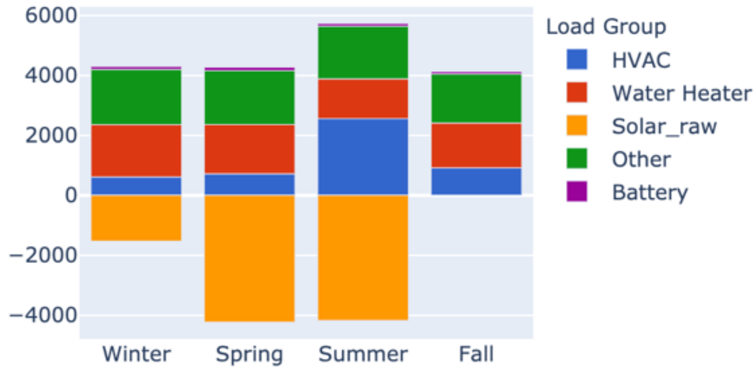
Source: EPRI

While there is a high potential shift load in the homes where resistive water heating is prevalent, there may be an even greater opportunity for grid benefit through load shedding through behavioral shifts from that of primarily "high demand" users to "efficient heat pump" users. A community composed of entirely efficient heat pump users would see very little impacts to the grid attributed to water heater loads, while the grid impacts are exacerbated if inefficient "high demand" users are prevalent.

Figure H-8 shows the breakdown in aggregated energy associated with each of the load groups and solar generation for the “efficient heat pump” user (left), the “mid-level” user (middle), and the “high demand” user (right).

Figure H-8: Seasonal Aggregated Energy by Load Group for Three Homes in Clovis Community in 2020





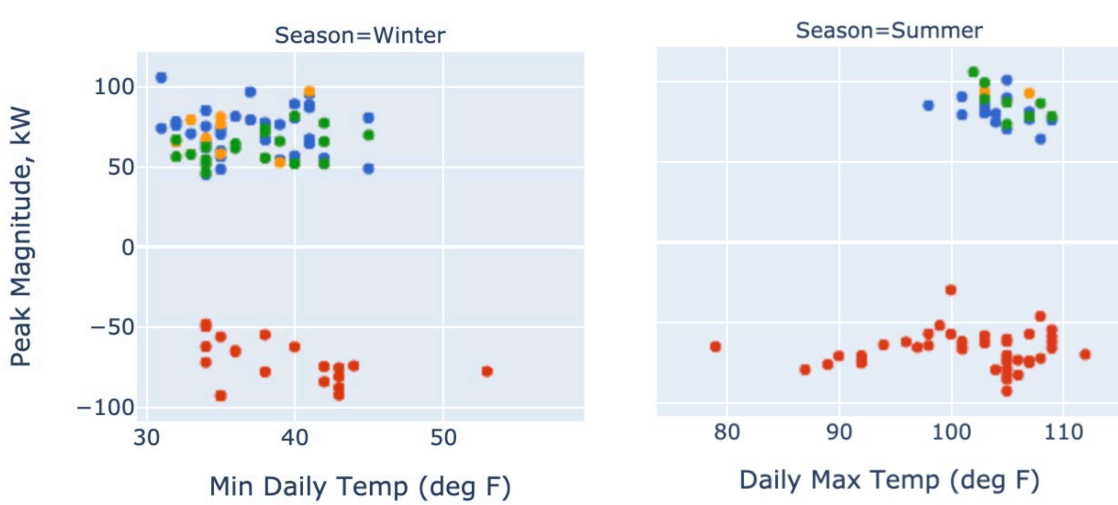
Source: EPRI

As expected, the portion of energy consumption from water heating increases as users increase their resistive water heating usage compared to the heat pump. In addition to the benefits to the grid, greater usage of the heat pump provides customer benefits through decreased energy bills.

Current Project Results – Community Peak Load Attribution

Peak load is defined as the largest absolute, minute-level kW recorded in the day. If the maximum absolute value is negative, the daily peak is assigned the negative value and attributed to solar. If the peak is positive (consumption-driven), then the peak is attributed to the end-use category with the largest load at the time of the peak. Because the main research focus of this study was to consider the potential of controllable loads to provide flexibility, loads were split into HVAC, Water Heater, Solar (a negative load), and Other for the aggregated non-controllable loads. Peak attribution to "Other" occurs when HVAC or Water Heater load is not larger than the remaining aggregated non-controllable load in the home at the time of peak. Winter daily peak magnitude versus minimum daily temperature and summer daily peak magnitude versus maximum daily temperature is shown in Figure H-9.

Figure H-9: Winter and Summer 2020 Clovis Community Daily Peak Load Attribution



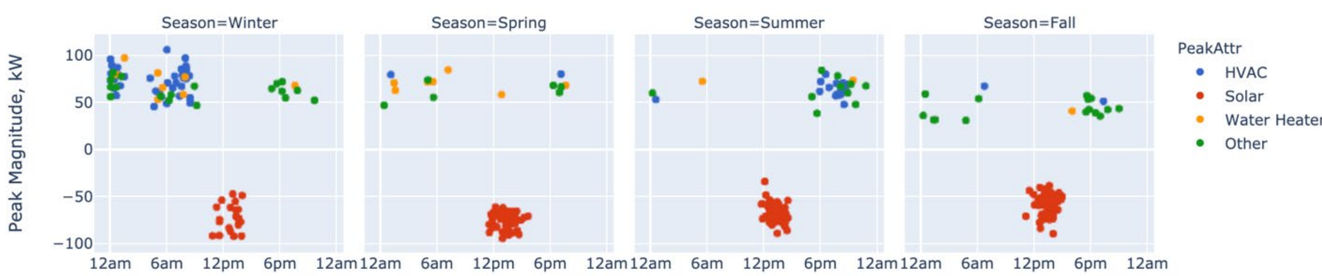
Source: EPRI

The largest peaks were recorded in winter, attributed to HVAC at just above 100 kW. The largest solar-driven negative peaks are similarly about 100 kW in magnitude. Summer positive peaks are slightly smaller in magnitude than winter peaks. Winter peaks could be larger due to coincident usage of HVAC and more prevalent resistive heating usage of water heater load.

Winter peak loads are not strongly correlated to minimum daily temperature. Summer peak loads have a small correlation to the maximum outdoor temperature. When the maximum outdoor temperature is below 100 degrees F, the daily peak is typically a solar-induced peak load, while higher temperature days contain a mix of daily peaks driven by solar production (negative peaks) and consumption-driven (positive peaks).

Figure H-10 shows the community peak load magnitude with attribution plotted against the time of day in which the peak occurs. In winter 2020, the cluster of peaks at midnight is likely due to increased EV charging from the dual EV charging coincident with HVAC consumption. The 6 am cluster peaks are driven by HVACN and water heater usage. Midday peaks across all seasons are negative in magnitude caused by the overgeneration of solar. Evening peaks in the winter are driven by other (non-controllable) loads. These peaks are smaller in magnitude than the morning winter peaks and are driven more by HVAC and Water Heaters, or the midnight peaks that are driven by HVAC and EV charging. In larger community datasets with greater load diversity, it is possible that different loads would increase in the contribution to the daily community peak load.

Figure H-10: Peak Magnitude with Attribution versus Time of Day in Clovis Community, 2020



Source: EPRI

Shoulder season peak loads are heavily weighted towards daily peaks during midday solar overgeneration. These large peaks reverse power flows, which are observed across all seasons, present a potential challenge to the grid.

Summer 2020 peaks that are not driven by solar are mostly driven by HVAC or the aggregated other non-controllable loads in the evening. A minimal water heater contribution to peak loads is to be expected in the summer when the heat pump can more reliably meet hot water demands and thus run in the more efficient heating mode.

Voice Assistants as an Enabling Tool to Enable Load Management in San Diego

These sites test the ability of voice assistants to engage homeowners and reduce energy consumption during peak periods using behavioral intervention, with potential for automated load shed.

Five homes in San Diego (CA CZ 7) were retrofitted with a variety of BTM DERs that included voice assistants, smart thermostats, heat pump water heaters, and circuit/AMI reading devices. See Table H-2 for the technologies installed within each home.

Table H-2: Technologies Installed in Five San Diego Homes

Home	Technologies Installed	Notes/Lessons Learned
1	Voice Assistant, AMI Meter Reading/Load Disaggregation, Heat Pump Water Heater and Smart Thermostat	Identification of a subcontractor for installing HPWHs was challenging.
2	Voice assistant, AMI Meter Reading/Load Disaggregation Tool, Smart Thermostat	The homeowner already owned a smart thermostat. However, access to coordinated control and data of this manufacturer was not available.
3	Voice assistant, AMI Meter Reading/Load Disaggregation Tool, Smart Thermostat	
4	Voice assistant, AMI Meter Reading/Load Disaggregation Tool, Smart Thermostat	
5	Voice assistant, AMI Meter Reading/Load Disaggregation Tool, Smart Thermostat	

Source: EPRI

The project was completed in four phases:

- **Phase 1 - High Rate Notification:** This phase provides the homeowner with a notification of a high rate period via a light change atop the voice assistant. The homeowner must engage with the device once the notification has been received to listen to the message. The message indicates that the homeowner's electricity rate will increase to X cents per kWh during the period.
- **Phase 2 - High Rate Notification + Recommended Actions:** This phase adds to Phase 1 by recommending actions that the homeowner can take based on the installed technologies within their homes. For instance, the voice assistant may suggest the following:
    - Avoid running the dishwasher or doing laundry during peak hours.
    - Increase (or decrease) the thermostat setpoints to reduce the energy used by A/C or Heating.
    - Turn off excess lighting to reduce energy usage during peak hours.

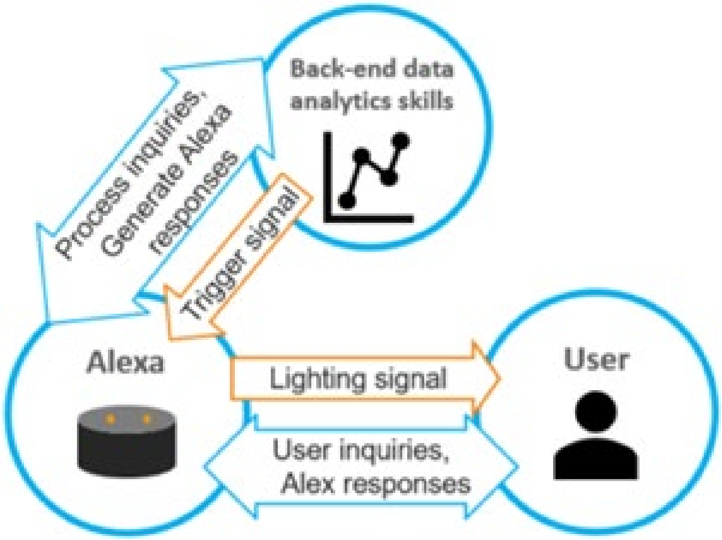
- **Phase 3 - Bill and Energy Consumption Calculations and Understanding:** This phase adds a means for proactive engagement with the voice assistant platform. Rather than wait for a notification, users can engage directly with the voice assistant by asking questions regarding their daily, weekly, or monthly energy usage as well as their energy bills. Backend data collection through the AMI meter and analytics provides near real-time calculations of energy usage for specified lengths of time and estimates energy bills.
- **Phase 4 - Automatic Load Control:** This phase adds the ability for the homeowner to opt-in to automatic control of their smart devices to reduce energy consumption during peak hours. For instance, during peak hours, the temperature setpoint on the A/C may increase to reduce usage. The homeowner can opt out of the mode during peak hours if their comfort is impacted by further engaging with Alexa.

To test the feasibility of the phases in the field, each phase was rolled out in the 5 homes starting in the spring shoulder season of 2020. The phases were then tested during the summer of 2020 to evaluate the effectiveness of each to reduce energy consumption at the home level using a voice assistant and/or automated control.

For Phases 1, 2, and 3, each time the voice assistant is engaged, the interaction is recorded in the form of a counter, establishing how often the voice assistant is engaged regarding energy consumption, bills, and high-rate periods. The AMI data collected proceeding each engagement was compared to similar energy consumption days without engagement to determine if there is any significant reduction in energy consumption as a result of engagement with the voice assistant. If no significant reduction is determined, at minimum, the counters will point to homeowner interest in such utility voice assistant interfaces. An additional counter will count and record when a homeowner opts out of Phase 4 automatic control, providing insight into if and/or how quickly, automatic control negatively impacts occupant comfort.

Figure H-11 illustrates the design of the voice assistant engagement, with the back-end data and analytics enabled by OpenDSRIP informing the signals sent to the device as well as calculating the responses to specific user prompts.

Figure H-11: Information Flow Diagram Between Voice Assistant, Customer User, and the Open Demand Side Resource Integration Platform

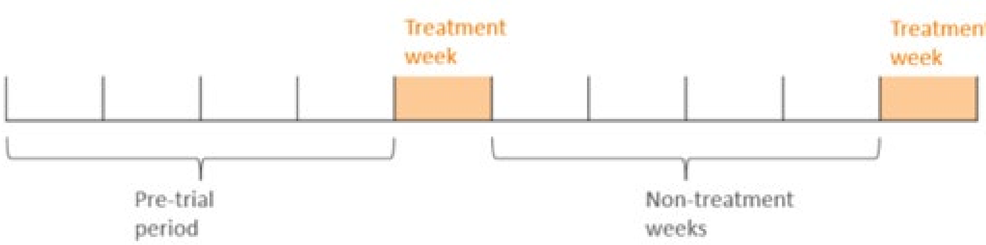


Source: EPRI

The schedule designs for Phases 1, 2, and 4 will follow a pre-designed schedule that accounts for the following rationales. See Figure H-12.

- Electricity price follows the Time-of-Use rate structure the customers enrolled.
- The experiment trial was divided into treatment weeks and non-treatment weeks to allow for distinguishing the impact of the lighting signal on energy use.
- During the treatment week, the voice assistant will send the orange lighting signal during the peak hours every day. During the non-treatment week, no lighting signal was sent.
- To distinguish the effect of engagement signals from seasonal consumption. At least one treatment week and one non-treatment week should be scheduled in the same summer season or winter season.
- Before the first treatment week, a pre-trial period should be considered to develop a baseline of consumption.

Figure H-12: Voice Assistant Signal Schedule Design in Phase 1, 2, and 4



Source: EPRI

Phase 3 was limited to recording how often the homeowner prompts the voice assistant using the given prompts to better understand their energy consumption and bills. Analysis of the post-engagement data will provide insight into if proactive engagement with the voice assistant can reduce energy consumption.

The impact of the engagement signal to end user behavior is measured by the metrics defined in Table H-3, including energy use, peak load shift, setpoint and other device setting parameter shifts. The metrics were captured in pre-study, non-treatment, and treatment periods and compared across these periods.

Table H-3: Proposed Metrics and Timescale

Metric	Device	Timescale
Energy Use	AMI	Daily/Hourly
Peak Load Shift	AMI	Hourly
Setpoint/Temperature/Other Value Shift	Thermostat/Water Heater	Hourly

Source: EPRI

Open Demand Side Resource Integration Platform in Small Commercial Demonstration Projects

The project team recruited three schools in Amador County, California (CA CZ 12). Each of these facilities with circuit level metering with software tools and the potential for controllable HVAC and lighting loads. The main research questions were:

- Can small/medium commercial buildings use cloud-based Building Energy Management Systems (BEMS) to identify opportunities for energy efficiency?
- Can Commercial Off the Shelf (COTS) cloud-based commercial BEMS feasibly provide mechanisms for facility managers to set up energy-efficient configurations across multiple behind-the-meter DERs without compromising on occupant comfort?
- Can COTS cloud-based commercial BEMS scale to provide appropriate load management and control functions in a fragmented DER market?

Demonstration Setup

Through another project conducted in parallel with this one (EPRI 2019b), the project team has experience recruiting over 100 different site locations. However, many sites chose not to participate or were deemed not feasible by the project team. Choosing not to participate included a lack of concern for energy bills, administrative approval requirements and responsibility for equipment during (they were leasing the building) and after the project was over. Technology requirements were building space and infrastructure challenges. In addition, several other sites presented challenges in data acquisition and controls implementation. The three sites presented were the sites containing the most data over a period (18 months) and presented the opportunity to establish the feasibility of controls.

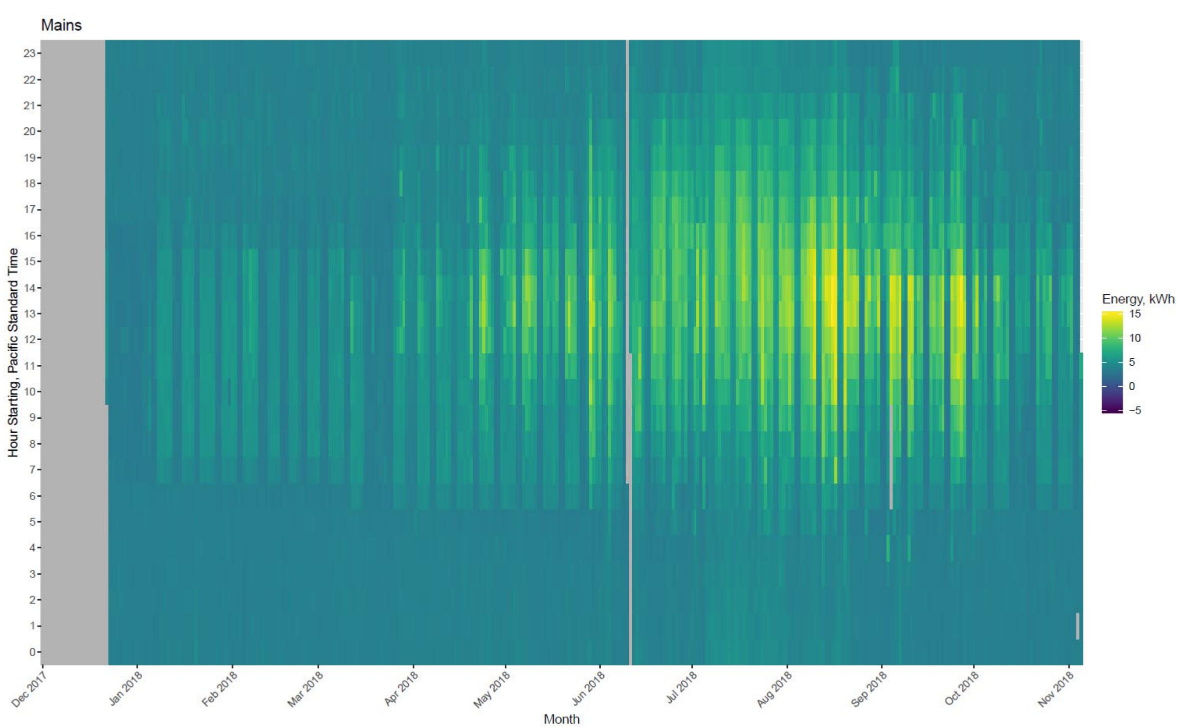
Summary Plots by Site

Summary plots were created for each site to help visualize the power values at an hourly and monthly resolution for the duration of the study. There are typically four load categories in this study: Mains, HVAC, Lighting, and Miscellaneous Monitored. Miscellaneous Monitored is the difference left over after subtracting HVAC and Lighting from Mains and can include loads as plugs loads and appliances. Depending on the availability of circuit-level monitoring labeling, Lighting or Miscellaneous Monitored may be missing or aggregated together into one category. Sometimes, there was an extra load of interest that is not under Mains. Some examples include a solar panel (PV) system or a pool pump. Missing or extra loads were noted for each site in their respective section.

Heatmaps show the power values at the hourly level, with months on the x-axis, the hour of the day on the y-axis, and the power value color-coded in the legend. In general, the legend is scaled to the maximum of the Mains for all plots to give a visual representation of the relative scale of that load.

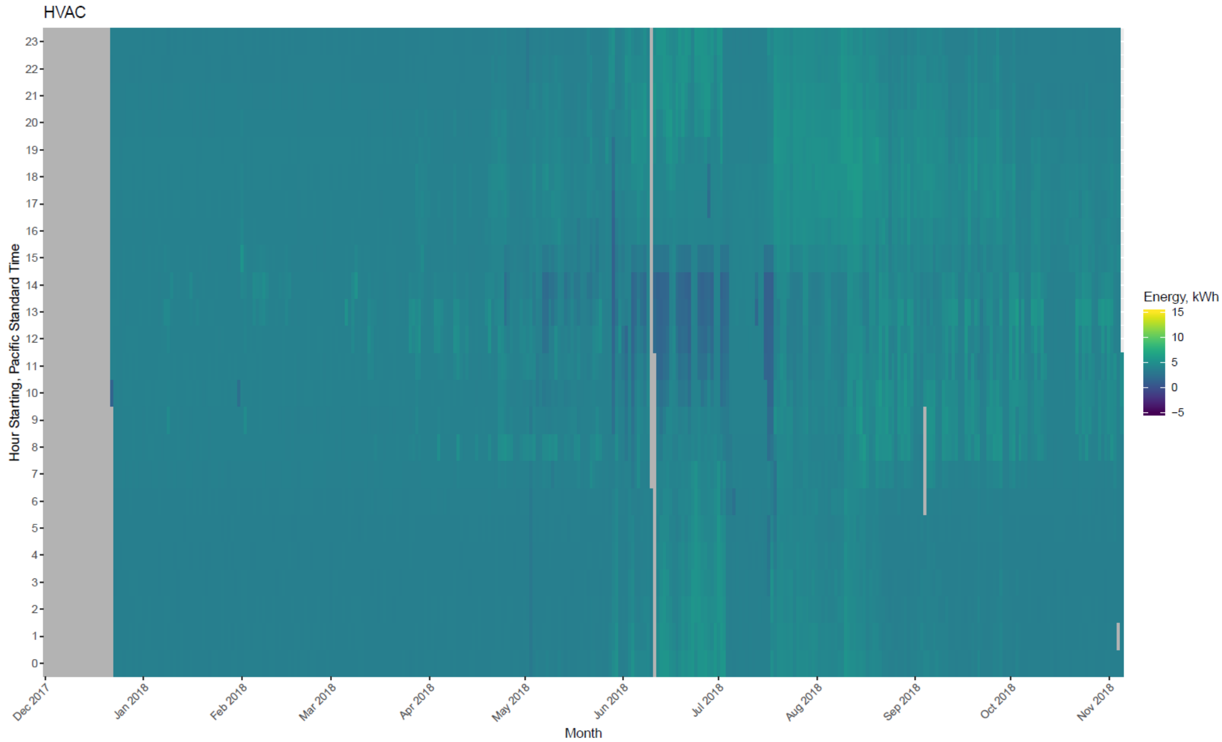
Bar plots show the total energy consumed per month, by load category. Boxplots show the general distribution of daily energy totals per month, by load category. The edges of the box are defined at the 25th, 50th, and 75th quartile. The whiskers of the box extend to 1.5 times the interquartile range (q25 to q75); values above and below the whiskers are considered outliers for that month. Boxplots are color-coded by weekday and weekend energy use. An example of using heat maps to identify opportunities is illustrated below. See Figure H-13 through Figure H-19: Bar Plots of Monthly Miscellaneous Monitored for heat maps, bar plots and box and whisker plots completed for one of the small to medium business sites.

Figure H-13: Heat Maps of Total Energy Consumption at One School



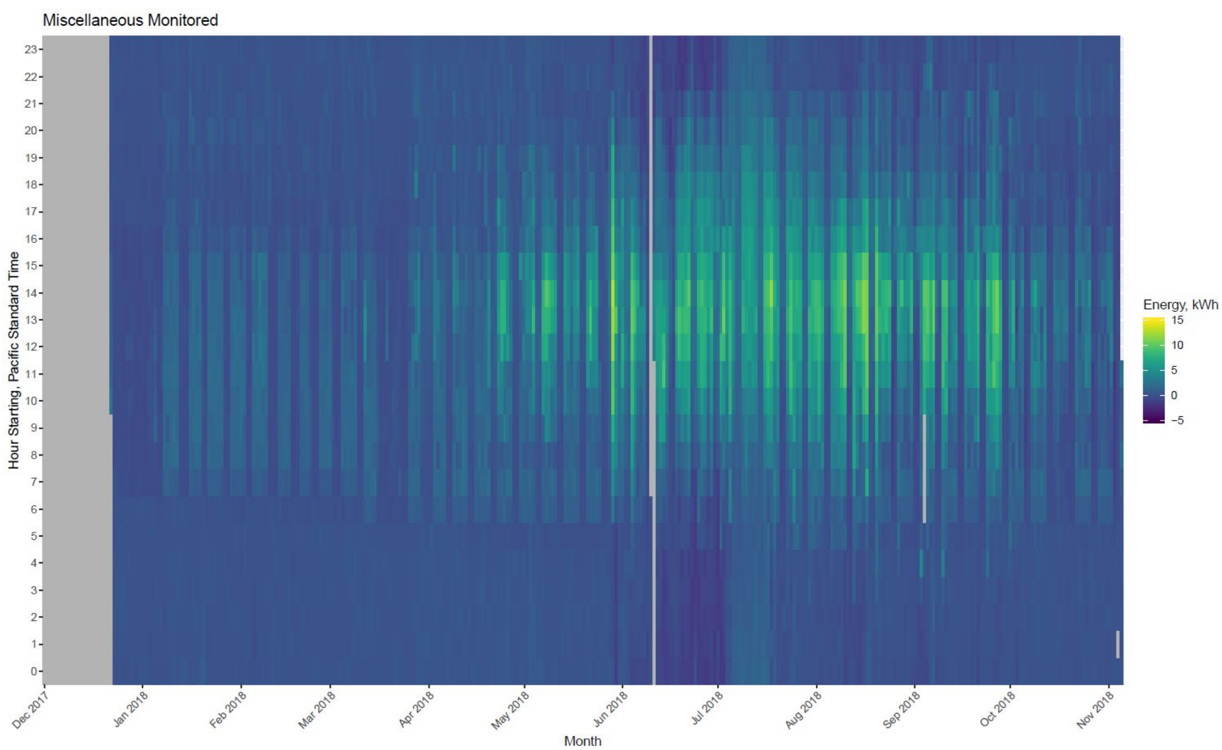
Source: EPRI

Figure H-14: Heat Maps of Heating, Ventilation, and Air Conditioning Loads at One School



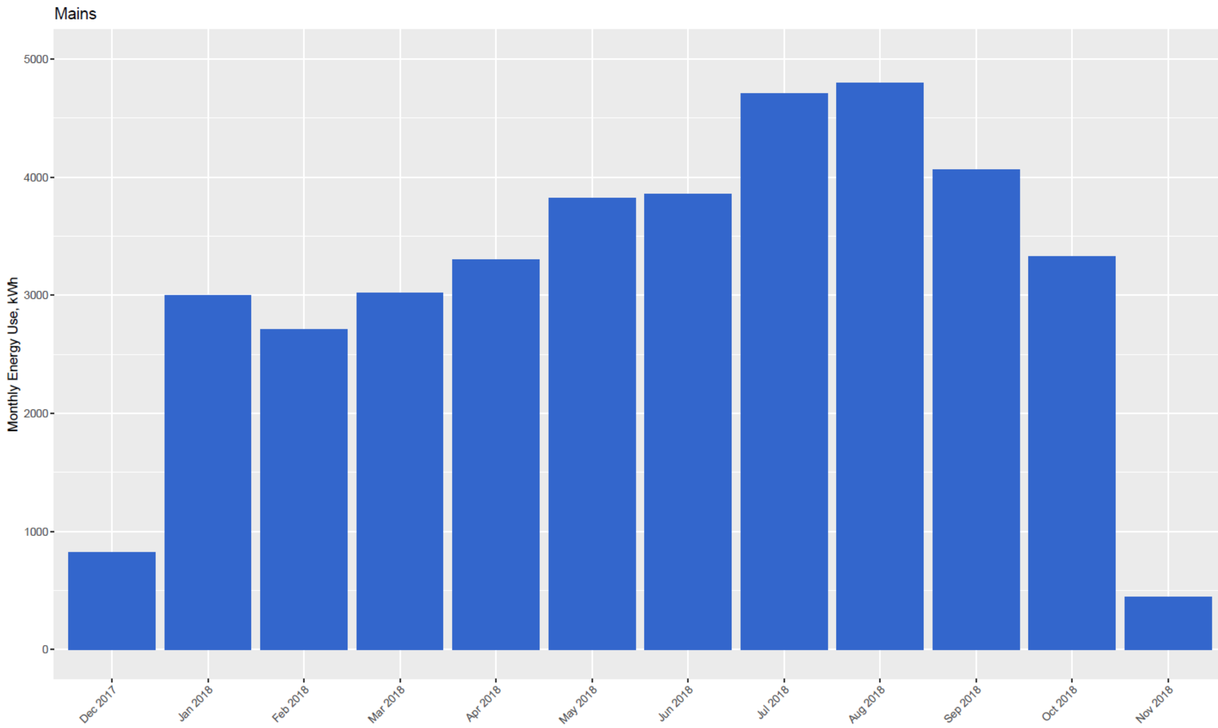
Source: EPRI

Figure H-15: Heat Maps of Miscellaneous Monitored Loads at One School



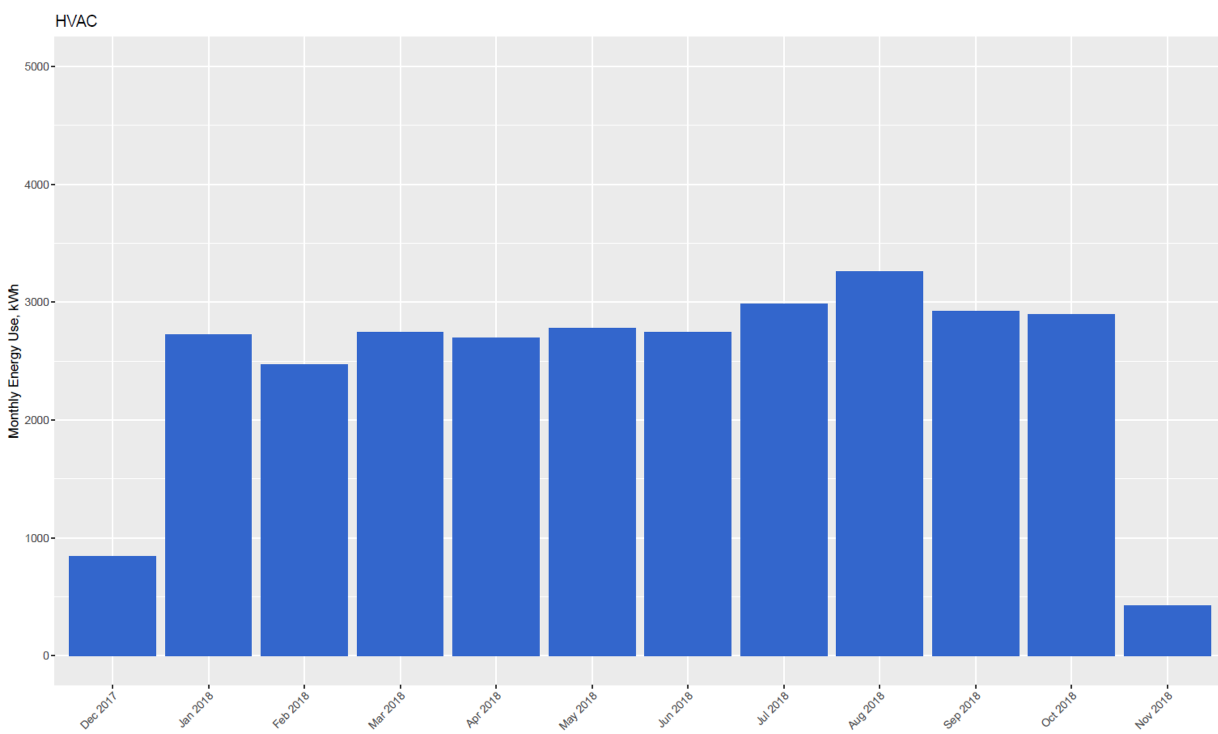
Source: EPRI

Figure H-16: Bar Plots of Monthly Electricity Usage at One School



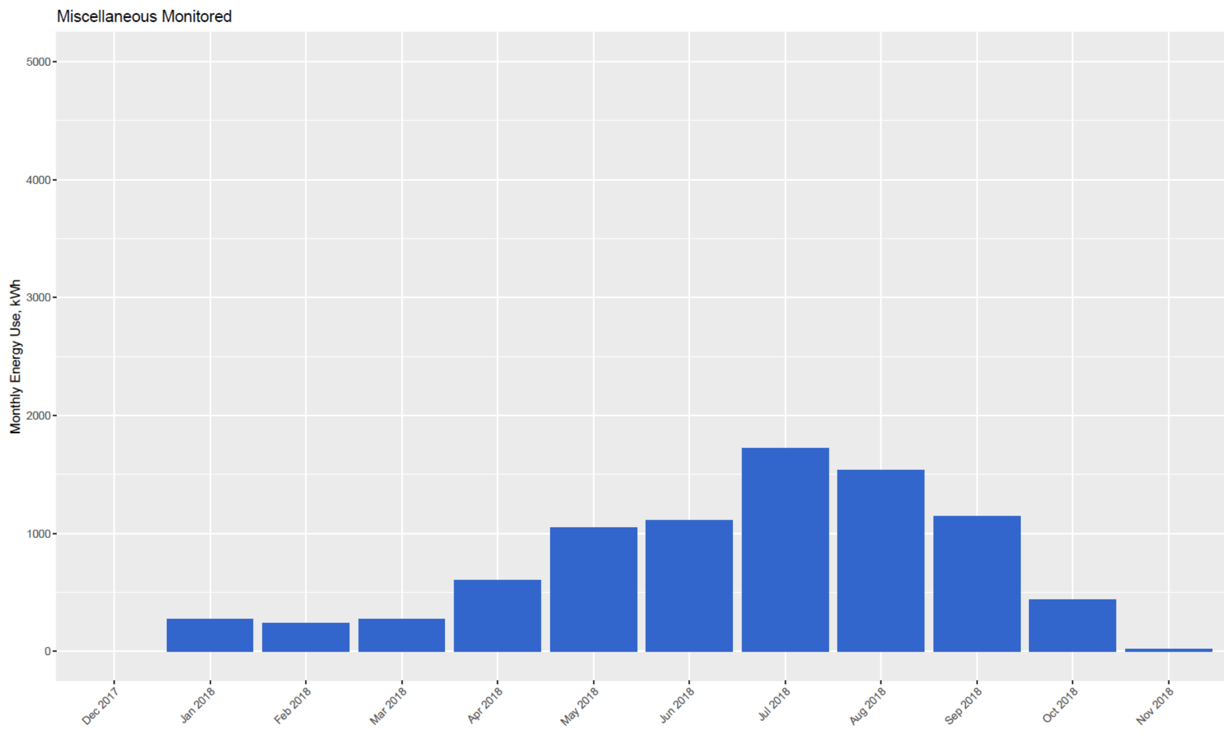
Source: EPRI

Figure H-17: Bar Plots of Monthly Heating, Ventilation, and Air Conditioning Electricity Usage at One School



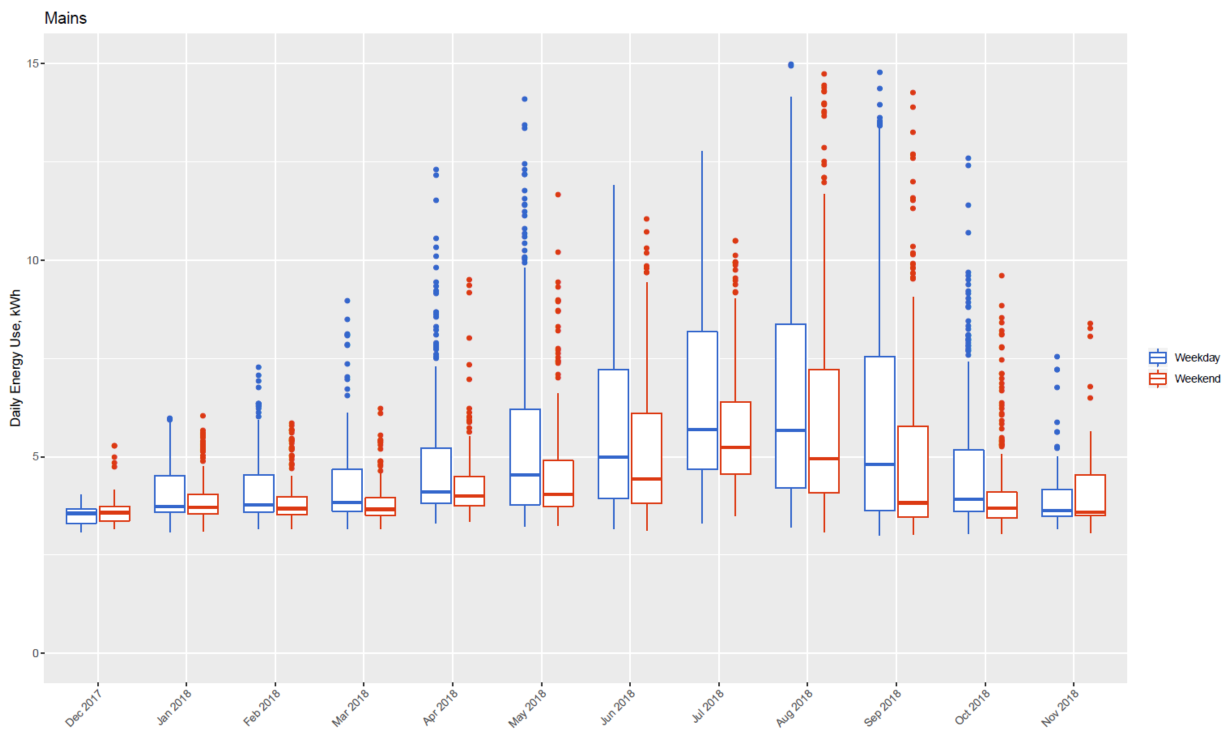
Source: EPRI

Figure H-18: Bar Plots of Monthly Miscellaneous Monitored Energy Consumption at One School



Source: EPRI

Figure H-19: Box and Whisker Plot Daily Energy Consumption of One School



Source: EPRI

Analysis Methodology

HVAC energy data from before the control date and after the control date is compared to evaluate the impact of an HVAC control device on the use of energy. To account for potential impacts of seasonal and daily temperature fluctuations, this is not computed with a simple difference in total energy use from before and after the control date. Rather, daily energy values from the after-control date period need to be weather normalized and compared to an appropriately matched daily energy value from the before-control date period. This process of weather normalization is done in two steps: 1) for the comparison of energy values in the heating season, and 2) for the comparison of energy values in the cooling season.

Weather normalization assumes that there is a linear relationship between degree days and daily energy values. A "degree day" is the general term for the difference in mean daily temperature and a baseline value. It was assumed that the baseline degree day value is 65 degrees Fahrenheit (60°F [16°C]). A heating degree day (HDD) is defined as the baseline temperature of 65°F (18°C) minus the mean daily temperature during the historical heating season. If that difference yields a negative number, then that day will not have an HDD value. In a hypothetical example, if the mean daily temperature on November 15 were 42°F (6°C) for a site in climate zone 3 (where November is a heating season month), then the HHD for that day is 23 HDD (65 - 42 = 23). Following the same hypothetical example, if the mean daily temperature on November 2 were 71°F (22°C) for that same site, then the difference is -6 and there is no HDD value for that day (65 - 71 = -6).

Conversely, a cooling degree day (CDD) is defined as the mean daily temperature minus the baseline temperature of 65°F (18°C) during the historical cooling season. If that difference yields a negative number, then that day will not have a CDD value.

The historical definition of the heating season and cooling season needs to be appropriately defined for each site for weather baseline construction. The historical seasonal definitions for heating season months and cooling season months are defined in the table below. The months are chosen based on the values in the References section of the report. For months where there were both HDD and CDD values, a strict interpretation of a heating or cooling season month was used such that months of the year were mutually exclusive, given the relative proportion of HHD to CDD values. In a hypothetical example, if October for site 4 had 600 HDD and 400 CDD, then that month would not be chosen as either a heating or cooling season. This is due to the nearly equal proportion of both HDD and CDD, which may potentially introduce noisy weather data values into the weather normalization process. In another hypothetical example, if October for site 12 had 700 HDD and 50 CDD, it would be chosen as a heating season month because of the relatively large proportion of HDD to CDD values. In that case, there is less potential for the introduction of noisy weather data values into the weather normalization process. In this case, we can define the heating season to be January, February, March, November and December and the cooling season to be July, August, and September.

Both before-control data and after-control data was heating, and cooling season month and outlier filtered before use in the weather normalization baseline model. For the heating season, the weather normalization linear regression model is constructed from the before-control data. Once this model is constructed, it is fed with after-control data to predict what the energy use would have been given baseline heating season weather. This value is computed for each day and the average expected daily energy is computed to determine what the estimated energy usage would have been. The linear regression model for the heating season is Daily Energy = Slope * HDD + Intercept. For the model to make physical sense, the Slope must be positive because there must be a positive linear relationship between HDD and Daily Energy. In general, the Intercept should be positive because it represents an energy value, and energy cannot be negative. In cases where the Intercept is negative, it could be due to noisy data skewing the linear regression model or it may indicate the need to adjust the degree day baseline from the standard 65°F (18°C) to another baseline value.

For the cooling season, the weather normalization linear regression model is similarly constructed from the before-control data. Like the heating season analysis, it is fed with after-control data to predict what the energy use would have been given baseline cooling season weather. This value is computed for each day and the average expected daily energy is computed. Restated, the cooling season weather normalization baseline model tells the analyst what the predicted Daily Energy Value should be, given the baseline weather conditions of the CDD value. The linear regression model for the cooling season is Daily Energy = Slope * CDD + Intercept. For the model to make physical sense, the Slope must be positive because there must be a positive linear relationship between CDD and Daily Energy. That is, more CDD days imply more daily energy use. In general, the Intercept should be positive because it represents an energy value, and energy cannot be negative. In cases where the Intercept is negative, it could be due to noisy data skewing the linear regression model or it may indicate the need to adjust the degree day baseline from the standard 65°F to another baseline value.

Controls Implementation Results

Controls implementation results for bill management were inconclusive as the project team experienced several challenges with implementation of building controls in these three schools. The project team investigated operational data from these three sites to identify opportunities for rate management in these buildings. Key findings are detailed below.

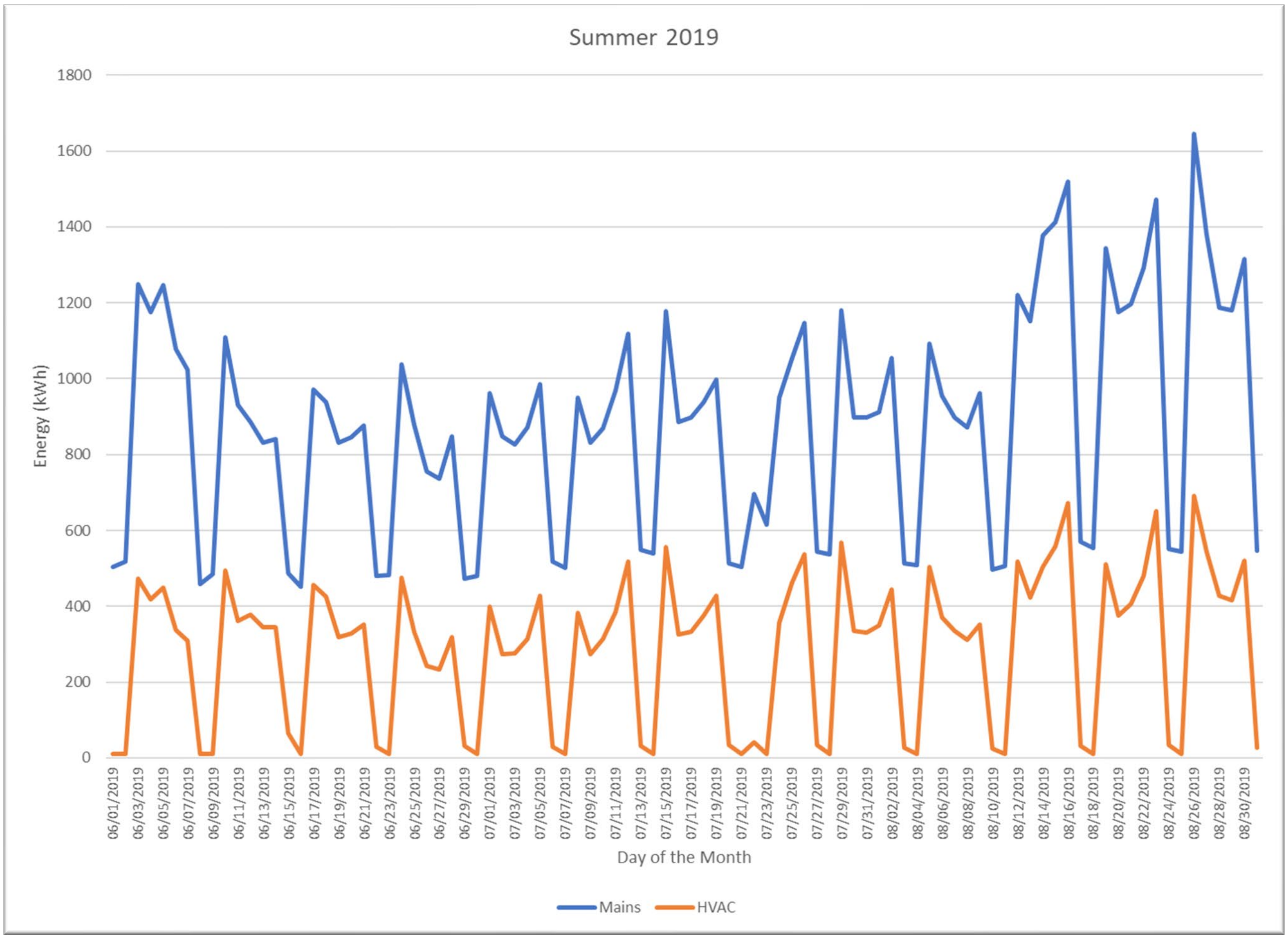
Key Findings

The project team identified many of the components to enable rate-based load management in these small commercial buildings, however, technology interoperability for the technical side, dynamic/volatile offering on the business side, coupled with the challenging overall cost-benefit analysis from the user side made it challenging to complete controls implementation. These facilities have different types of HVAC systems ranging from commercial chillers to variable-speed HVAC systems with air handlers. These three sites contained thermostats installed that allow for zone-level scheduling and control of HVAC loads by the BEMS. The BEMS provides rules-engine based orchestrated control of loads based on a set of triggers such as electricity price, time-of-day, etc. and allows a set of actions ranging from informing the facility manager via SMS/Email to automatically setting back thermostats to reduce cooling loads. The BEMS did provide interfaces with DSRIP to receive pricing signals and provides DSRIP energy and building-level DER operating data.

Identifying Opportunities for Energy Efficiency

Results from one of the schools monitored are provided here by looking at the disaggregated load shapes of the HVAC load and comparing it to the mains loads, this indicates that the shape of the overall mains is heavily dependent upon the HVAC load, however, there is a significant non-HVAC load component that contributes to the overall load (Figure H-20).

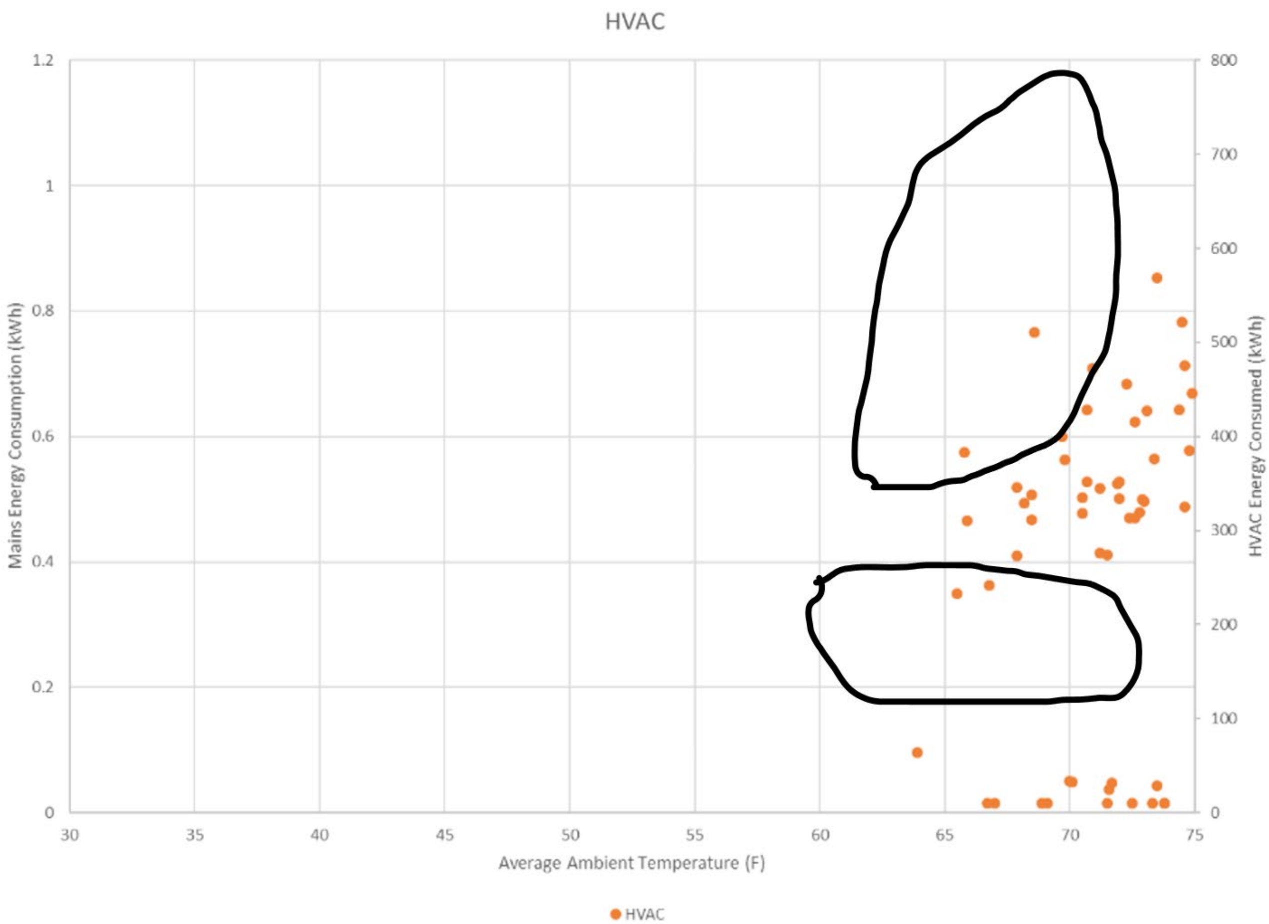
Figure H-20: Summer 2019 Mains and Heating, Ventilation, and Air Conditioning Loads at One School



Source: EPRI

Finally given the aggregated nature of the data from DSRIP, further investigation into the effects of daily average ambient temperature on the HVAC and Mains can be understood. Figure H-21 shows the HVAC and Mains consumption as a function of average ambient temperature. There are two interpretations (a) there are two distinct clusters pertaining to weekdays and weekends (the cyclical short periods of low consumption indicate the same), and (b) the positive correlation of HVAC consumption with respect to the average ambient temperature.

Figure H-21: Dependency of Heating, Ventilation, and Air Conditioning Load on Average Ambient Temperature

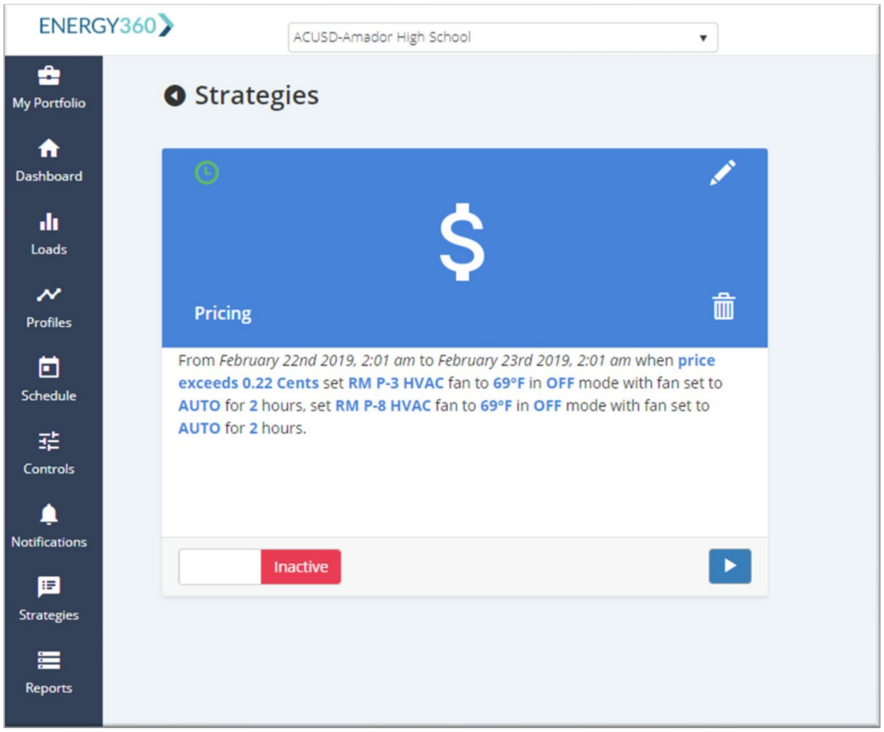


Source: EPRI

Feasibility of Load Management in Response to Dynamic Pricing Signals

To automate load management contingent upon a set of conditions, the BEMS provides a "Strategies" rules engine that allows facility managers to set up triggers for action along with the specific set of actions. Figure H-22 shows a pricing-based energy management strategy that was set up by the facility manager. The project team identified that the strategies engine was not properly commissioned nor interfaced correctly with OpenDSRIP to enable strategies. However, this software module potentially provides rate-based coordinated control and load management like IFTTT functions in the residential space discussed in Chapter 2.

Figure H-22: Price-Based Strategies Enabled by Commercial Building Energy Management System



Source: EPRI

Scalability of Load Management

Scalability considerations for commercial buildings energy management are heavily dependent upon identifying critical loads and controlling non-critical loads through appropriate 3rd party integrations subject to occupant comfort constraints. In general, scalability is addressed through vendor-proprietary point-to-point integrations between BEMS vendors (for example, Schneider Electric, Siemens, etc.) and commercial HVAC systems and thermostats (for example, Pelican, Honeywell, etc.). Emerging paradigms in commercial buildings such as Solar + Storage + Load Management require specialized controller development and more industry fragmentation to handle different types of PV inverters, batteries and associated battery energy management systems, and building automation systems.

Electric Vehicle Load Management Using an Open Vehicle-to-Grid Integration Platform

The Open Vehicle to Grid Integration Platform (OVGIP) can manage the interaction of Plug-in Electric Vehicles (PEV) or Plug-in Hybrid Electric Vehicles (PHEV) and the grid for charging based on the dynamic energy pricing and user behavior. The core process starts with the EPRI VTN that sets up pricing tariffs discussed in Chapter 2. However, it is important to note that the VTN is designed to work with various market contexts depending on territory, IOU or any defined Load Aggregation Points (LAP). The IOUs or the Utility can set up the price tariffs for their market segments on the EPRI VTN. The core protocol supported by the VTN is OpenADR

2.0b. Once the price tariffs are uploaded, there are two architectures that could be used to manage the vehicles as demand resources:

a. Use an EPRI VEN (Virtual End Node) which is a client in a client-server context that can either poll for data from VTNs or be informed of data when it is uploaded on the server. The VEN will now be able to get the price tariffs for the market context or segment under consideration. Many clients working for different market contexts can be used to get the price tariffs from the VTN.

b. In this case, the client could be a cloud-based app interacting with the DSRIP platform. The DSRIP platform also contains a client that will get the tariffs for all market contexts, and it exposes an API (Application Programming Interface) wherein a cloud based or IOT type embedded device can gather the tariffs from the DSRIP platform. The cloud-based app (as a client of the DSRIP platform) would be able to get the tariffs for the market context of interest.

In both the above cases, data reaches the OEM server using secure internet protocols. Figure H-23 provides more details on how signals received by openADR2.0B VEN are translated to JSON format.

Figure H-23: OpenADR2.0B VEN Translated into JSON Formats


```
{
  "ver": "1.0",
  "kind": 5,
  "signalid": 123456678,
  "utility": 1,
  "data": [
    {
        "common":
        {
            "area": "94123",
            "begindate": "2016-04-01T00:00:00Z",
            "enddate": "2016-07-01T23:59:59Z",
        },
        "tariffs":
        [
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                "endhour": "07:59",
                "value": 0.10,
                "unit": 8
            },
            {
                "beginhour":"08:00",
                "endhour": "08:59",
                "value": 0.15,
                "unit": 8
            },
            {
              ......
            },
            {
              ......
            },
            {
              ......
            }
        ]
    }
  ]
}
```
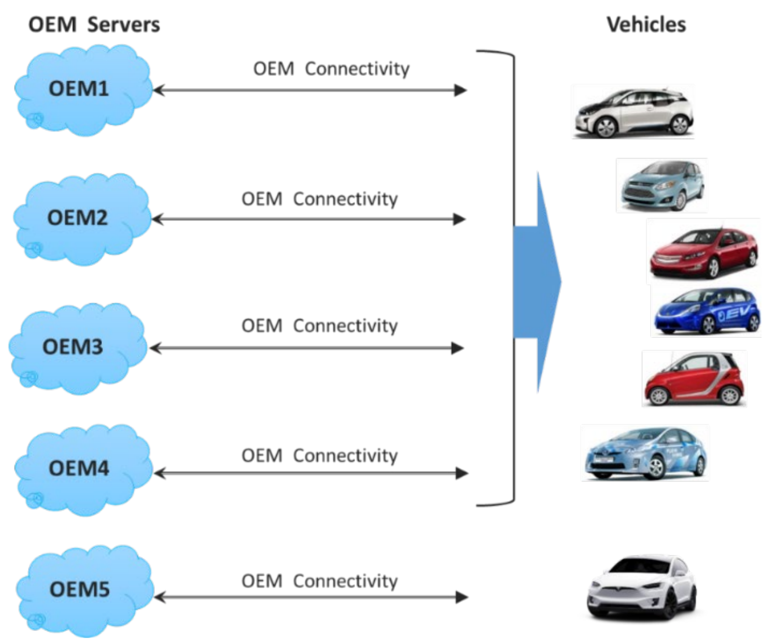


Source: EPRI

In case (2) above, the cloud-based app implements a client-based interface, which uses well-defined API calls to retrieve the price tariffs. The app then computes the required charging slots and uses API calls provided by an OEM to control a specific vehicle after user authentication. This communication now goes to another OEM cloud server. An example of such a system is an OEM which could potentially expose an API to control individual cars (after user authentication).

The next steps are managed by the OEM. In the next steps, each OEM server communicates to their vehicle through their proprietary protocols and networks. In case (1) above the OEM servers handle the computation of charging slots, user preferences, opt-in and opt-out. The OEM servers use their protocols to communicate with the individual vehicles, and this happens in their network infrastructure. The information collected for the charge session is then periodically collected and transmitted manually. The main concern is the posting of user-specific data and information to the platform. This data has been collected and managed by the OEMs along with their vehicles involved in this system, and there seems to be some hesitation to share this data openly without additional controls and licenses. In case (2), the OEM server simply routes the data to the vehicle as it has been previously authenticated with the app in the cloud and the user. The individual connections are shown schematically in Figure H-24.

Figure H-24: Original Equipment Manufacturer Servers as an Aggregator of Specific Electric Vehicles



Source: EPRI

A generic process of such a system functioning involves the following steps:

- User is notified with an email that includes a link to an app download or an OEM website link for user interaction with the system.

- User installs an app and updates the user profile including zip code, and other relevant information. A similar process is adopted when the user logs into the OEM website.
- Next, the utility in that zip code is provided to the user who will confirm the Utility and IOU that they are currently registered to.
- The user then accepts the terms and conditions of the system either on the app or the website.
- At this point, the user is registered and can monitor the process that involves their vehicle. They can adjust parameters and accept or change schedules as per their need.

CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix I: Technical Advisory Committee

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APPENDIX I:
Technical Advisory Committee

The project team assembled a technical advisory committee (TAC) comprising of different stakeholder groups to elicit feedback on elements of the project during its PoP. TAC members were also used to help contextualize results and provide additional secondary research and feedback on the results and lessons learned from designing demonstrating and deploying OpenDSRIP part of this project. TAC member roles were accurate as of the time in which they contributed to the TAC. See Table I-1.

Table I-1: EPRI Technical Advisory Committee Members

Member Name	Organization	Role
Ryan Harty	American Honda Motor Co.	EV Project Partner
Adam Langton	BMW	EV Project Partner
Jeff Hamel	Nest Labs	Thermostat Project Partner
Mark Thomson	ThinkEcSmart Plug/Room A/C Project Partner	
Peter Black	Ecobee, Inc.	Thermostat Project Partner
Walt Johnson	Electric Power Research Institute	15-311 Group 3 Awardee PM
Suzanne Frew	Snohomish PUD	IDSM Program Manager Snohomish PUD
Matt Johnson	EnergyHub, Inc.	Residential DR Platform Provider
David Logsdon	Consolidated Edison	DR Program Managers at ConEd
Zach Sussman	Consolidated Edison	DR Program Managers at ConEd
Sam Delay	Tennessee Valley Authority	Emerging Technology R&D Leads at TVA
Drew Frye	Tennessee Valley Authority	Emerging Technology R&D Leads at TVA
Yoshimitsu (Yoshi) Goto	Innovation Core SEI, Inc.	OVGIP Project Partner
Duane Pearson	Salt River Project	SRP Sr. Project Manager
Jason Dudley	Salt River Project	SRP Project Manager
Matthew Tolliver	EcoFactor, Inc.	Smart Thermostat Service Provider
Ganesh Ayer	Honeywell Smart Grid Solutions	Smart Thermostat Service Provider
Teja Kuruganti	Oak Ridge National Laboratories	Transactive Energy Subject Matter Expert
Ron Robertson	Gulf Power	Utility Smart Thermostat Project Manager

Member Name	Organization	Role
Craig Smith	Seattle City Light	Director of Emerging Technologies @ Seattle City Light
Mike Little	Seattle City Light	Manager of Emerging Technologies at Seattle City Light
Ann Perreault	Honeywell Smart Grid Solutions	Thermostat/Connected Home Project Partner
Siva Iyer	Carrier Inc.	Connected HVAC Project Partner
Ansul Rajgharia	Schneider Electric, Inc.	Wiser Energy Partner
Beth Reid	Olivine, Inc.	Project Partner
Mimoun Abaraw	Lennox, Int'l.	Connected HVAC Project Partner
Hilen Cruz	Salt River Project	SRP Customer Program Lead
Bill Hosken	AO Smith	Water Heater Manufacturer Lead
Helmut Goehle	Sun Run	Sr. Director, New Homes
John Hughes	Ingersoll-Rand	HVAC Controls Engineering Lead
Erik Norwood	Curb, Inc.	CEO of Circuit Level Monitoring provider
Felix Cheung	Rheem Water Heaters	Connected Water Heater Provider
Rodney McCall	Pentair	Pool Pump Provider
Ankur Maheshwari	Rheem	Connected Water Heater Provider
Brandon DeYoung	DeYoung Properties	Home Builder
Rachna Handa	OSISoft	Data Aggregation of Utility Systems
Therese Peffer	UC Berkeley CIEE	Also 15-311 Group 2 Awardee
Tilak Gopalarathnam	LG Electronics	Connected Appliance Manufacturer
Winifred Liu	LG Electronics	Connected Appliance Manufacturer
Christopher Kelson	Whirlpool	Connected Appliance Manufacturer
George Gurlaskie	Duke Energy	Utility DR Lead
Elena Hill	KCP&L	Product Manager, Energy Solutions
Phil Markham	Southern Company	Smart Buildings Manager
Jim Leverette	Southern Company	Smart Buildings Engineer

Source: EPRI