EPC-15-074: Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems

Task 2: Distributed Energy Resources Portfolio Report

August 25, 2017

Prepared for

California Energy Commission

Prepared by

Center for Sustainable Energy

Center for Sustainable Energy®

Cite this reference as 2017, Portfolio Report, Center for Sustainable Energy.

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I. Executive Summary

The primary goal of the ***EPC-15-074: Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems*** project is to develop operational strategies that allow behind-the-meter, distributed electricity resources to be bid into the wholesale market—primarily as proxy demand resources (PDR)—while still maintaining their intended value and service to the customer. The first step in aggregating and bidding resources into the wholesale market is to choose customers, sites, and technologies that meet the requirements set forth by the California Independent System Operator (CAISO). The project team comprised of Center for Sustainable Energy (CSE), SolarCity Corporation, Conectric Networks, Olivine Inc, and DNV GL worked with multiple potential customers across numerous sites and eventually identified seven sites[1] that will participate in the project. Five of the sites are schools in Chino Hills, CA that will be aggregated into a single PDR with each site using battery storage with a combined capacity of 1.1 MW/2.09 MWh. Two other sites are hotels in San Diego that will be aggregated into a single PDR with the ability to reduce onsite load by up to 215 kW/ 1,300 kWh with automated sensors and smart controls on HVAC equipment, appliances and lighting.

This report describes in greater detail the locations, customer types, and technologies to be used in the two separate aggregations, as well as the lessons learned and commercial, technical, and regulatory barriers experienced by the project team in soliciting customer participation in the pilot.

In summary, the lessons learned and barriers identified during the customer site selection process included:

- Customers are eager for revenue-generating opportunities such as demand response (DR)
- There is limited understanding of the risks and economic benefits of PDR participation
- PDR eligibility and enrollment processes are currently difficult for customers to understand
- Existing PDR rules may be prohibitive for certain types of customers or technologies to enroll or participate as PDR

Overall, enhanced education regarding PDR rules and opportunities could address many of the barriers experienced. To allow more customers and sites to enroll as PDR, the project team suggests streamlining educational materials for both project developers and customers. For example, the CAISO could implement more customer-friendly educational materials, flow charts, and training modules to describe the rules, potential economic value, and benefits of PDR participation. Streamlining and simplifying the customer education process would be beneficial in enrolling more customers and demand response

[1] Importantly, it should be noted that the sites described in this report are strongly committed to the project as of August 25, 2017. Until fully registered into the wholesale market as PDR, customers and/or sites are subject to change. While unlikely, if there are customer or site changes to either portfolio, these changes will be noted in future reports.

capacity into the wholesale market, providing greater monentizable and non-monetizable benefits to California's grid, ratepayers, and environment.

II. DER Portfolio Description

The EPC-15-074 project (referred internally as "EPIC STEEL") is made up of two portfolios. Portfolio 1 uses behind-the-meter battery storage while Portfolio 2 uses real-time occupancy, load sensors and controls to shift onsite load. Figure 1 demonstrates the respective technical capabilities and operating constraints for each portfolio.

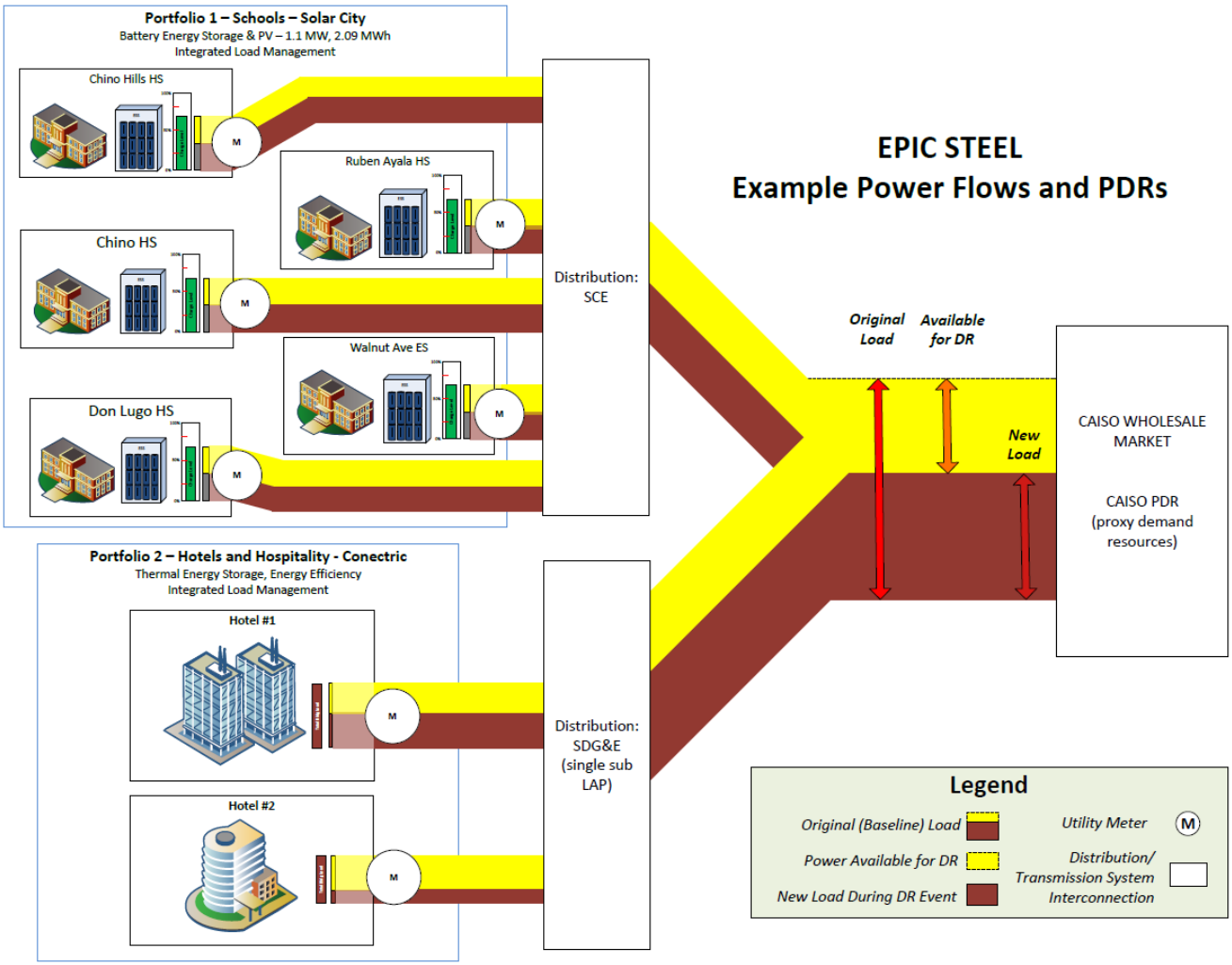

Figure 1: A demonstration of the two separate portfolios and power flows. The two resources are shown on the left with representative power sources and/or controllable loads. Load reduction is shown in yellow, aggregating across distribution systems into the wholesale market representation on the right.

Portfolio 1 – Aggregated Battery Storage

Portfolio 1 comprises five schools located in Chino Hills, CA that will be aggregated as a single resource. Each site will use energy storage to discharge to the onsite load and reduce electrical demand from the grid when participating in the wholesale market. Each battery can discharge at its rated capacity for up to two hours and is based on the powertrain architecture and components of Tesla's electric vehicles, with optimizations in design and cell chemistry for grid-connected stationary energy storage applications. The batteries are designed to cycle up to 365 times per year. The batteries are fully-integrated AC energy storage systems, and each DC battery pack comprises of:

- 16 battery "pods" connected in parallel to a common internal DC bus
- Each pod consists of battery modules with an isolated DC-DC converter
- Integrated liquid thermal management system
- Battery Management System (BMS)
- Single DC and communication interface
- DC cable harnesses between battery packs (to be installed at site)
- Communication cable harnesses between battery packs (to be installed at site)
- Bi-directional inverter
- Site Master Controller (SMC)
- Tesla's Control and monitoring software

In addition to energy storage, each school also has onsite solar photovoltaics (PV). While the solar PV is used to reduce onsite load, since it is a non-dispatchable resource, it is not used to control and reduce load when bidding into the wholesale market.

The schools are all served by Southern California Edison (SCE). The site name, address, storage power (kW) and energy (kWh) capacities, and solar PV capacity (kW) are each listed in the table below.

Site Name	Address	Battery Resource	Solar PV Size
Chino Hills HS	16150 Pomona Rincon Rd, Chino Hills, CA 91709	250 kW/475 kWh	1,078 kw
Chino HS	5472 Park Pl, Chino, CA 91710	250 kW/475 kWh	707 kw
Don Lugo HS	13400 Pipeline Ave, Chino, CA 91710	250 kW/475 kWh	904 kw
Ruben Ayala HS	14255 Peyton Dr, Chino Hills, CA 91709	250 kW/475 kWh	1,116 kw
Walnut Ave ES	5550 Walnut Ave, Chino, CA 91710	100 kW/190 kWh	168 kw
Total		**1,100 kW/2,090 kWh**	**3,973 kw**

Table 1: Four high schools and one elementary school have been selected to make up the resource for Portfolio 1. The sites are all located within the same Southern California Edison sub-LAP.

Lessons Learned from Portfolio 1 Site Selection

Customer Engagement – During the customer site selection process for Portfolio 1, the project team learned that in-depth customer engagement was required to educate and enlist customers into the PDR portfolios. A significant amount of project developers' time was spent educating host customers on how their behind-the-meter resources could be a valued commodity by participating in the wholesale electricity market.

Onsite Solar PV Considerations – The project team also learned that eligibility of behind-the-meter electricity resources for wholesale market participation can be quite limited, especially for customers with rooftop solar PV. PDR in the CAISO wholesale market does not compensate for electricity exports. Thus, creating a siloed valuation of the potential customer and grid benefits from engaging in active load management and demand response versus solar PV production occurring on the same host site.

Host Customer Internal Timelines – Developers should consider the decision-making processes and associated time needs of potential host customers. For example, if the host customers are public entities, such as schools, then they may require board approval before participating in supply-side demand response programs. If such is the case, then project timelines should be adjusted to account for host customer internal timelines when selecting sites and preparing to register resources in the wholesale market.

Portfolio 2 – Advanced Load Management

Portfolio 2 will seek to illuminate the potential for active "deep" load management in hotels and hospitality sector meeting grid needs based on wholesale electricity market prices. This portfolio comprises two medium-large hotels in San Diego County that will be aggregated together as a single PDR resource. The PDR resources will have a maximum load reduction capacity of 160 kW – 215 kW for 4-6 hours (640kWh – 1,300kWh). The amount and duration of load reduction changes depending on several factors, including season, weather, and time of day.

Portfolio 2 will deploy a suite of sensors, software, and controls to reduce and shift load as needed. Below is a description of the technologies and approach used in Portfolio 2:

1. Digital Asset Classification Software: Software is used to perform historical statistical time series analysis on recorded interval meter data to segregate load behavior into three general categories:
    a. Base load (24/7 electrical consumption).
    b. Variable weather-dependent load (potentially controllable mechanical systems impacted by weather).
    c. Variable non-weather-dependant load (potentially controllable mechanical/electrical systems impacted by building occupancy).
2. Distributed Energy Auditing App: Software is used to perform an ASHRAE standard building energy audit and scheduling for controllable equipment.
3. 802.15.4 IoT Mesh Network: The wireless data network, based on 802.15.4 networking standards, is implemented with at least 1 Linux-based mini-computer gateway, LTE data

backhaul (currently carried over T-mobile network), and a series of routers used to transport data from distributed building sensors.

4. Wireless battery-powered sensors: Battery-powered sensors detect ambient air temperature and humidity, door position in each room, serial data sources[2] and Passive Infrared signatures (human occupancy). Temperature senors are distributed throughout the building air supply and return ducting to identify thermal and mechanical behaviors of existing systems and structures. Additional sensors are used to profile zone occupancy behavior and patterns.
5. Sub-metering: Sub-meters for major mechanical and electrical systems are installed to match statistical meter data, sensor network data, and prediction algorithms to real time energy demand and consumption.
6. Zone controllers: Zone controllers are used for analog and electric switching of controllable loads, such as ventilation, chilled water loops, pumps, and other identified controllable loads.
7. Wall interface devices: These are used to drive zone controllers based on occupant-desired settings, run embedded operating systems, route sensor data traffic, perform algorithmic (AI) control strategies, accept (AI) demand control management, and provide zone occupancy data to edge gateways.
8. Data aggregation: A distributed serverless cloud is used to aggregate data acquired from edge gateway devices run on Google Cloud Platform. Management of Internet of Things (IoT) devices.

Through the software, sensors, and data analytics, each hotel site will continuously monitor business and occupant energy needs and actively reduce energy-consuming loads not needed by the business or occupants. The load control software can manage tens of thousands of micro loads based on actual requirements for energy to operate the building per its business reuqirements and occupancy comfort. Each controllable load is considered “available” or “un-available” inventory based on real-time sensor data. Extensive testing and calibration of the software and sensors’ data will be necessary to maintain a dynamic, optimal balance of maintaining building occupants’ comfort, running important business operations, and providing load reduction at moments when wholesale electricity market prices are high.

[2] Conectric can extract this through its “RS485 Sensor” and transmit the data source wirelessly into the Edge Gateway for further analysis.

Lessons Learned from Portfolio 2 Site Selection

Customer Desire for Simplicity – Through the site selection process for Portfolio 2, the project team learned that customer engagement increases dramatically when a pitch is made on the virtues of energy efficiency, demand control, and demand response using industry-specific financial metrics and terminology regarding investment risks and benefits. In addition, retail rate structures are becoming increasingly complex and are surpassing the ability to effectively manage energy and building systems behavior, particularly the building operator's ability to manage energy consumption based on price signals. Systems of Intelligence, dynamic load controls, automation, IoT, and cloud solutions are an opportunity to increase buildings' ability to respond to price signals and manage load, and building operators are often willing to deploy these technologies to simplify their energy management. Therefore, there is a high demand and need for more dynamic and autonomous forms of load management in this sector.

Site Analysis Timeline and Software Automation – The project team spent 6 months on site analysis to select sites suitable for wholesale participation due to the lack of detailed load information. Although the customers did not pay for the analysis, they are wary of the time involved. A site selection and analysis process less than 30 days would be more appealing to customers, which could be attained through an increased level of automation analyzing and/or data collection to enhance the development and characterization process.

III. Barriers in Aggregating DER Portfolio

CAISO Proxy Demand Resources Rules Impacting Site Selection

The two portfolios will participate in the wholesale market as Proxy Demand Resources (PDR) and must therefore abide by the CAISO's PDR rules. Some of these rules, discussed below, may impact site, customer, and portfolio selection.

Direct Access Customers – Direct Access customers are eligible to participate in the market as PDR, but if they are part of a larger aggregation, all other aggregated customers must also be Direct Access customers. Therefore, Direct Access customers must be aggregated separately from retail customers.

Aggregation – PDR can be comprised of a single asset or multiple, aggregated assets if the aggregated assets are located within the same sub-load aggregation point (sub-LAP). A sub-LAP is a specific geographical region within the CAISO-controlled electric grid that is generally demarcated by electric transmission and sub-transmission lines and transfer station points. There are multiple sub-LAPs throughout California.

Minimum Load Reduction – A resource, comprised of either a single or multiple assets, must be able to reduce 100 kW of onsite load to register with the CAISO as a PDR, although the resources can bid less than 100 kW of load reduction when participating in the market.

Telemetry – PDR equal to or greater than 10 MW are required to have telemetry, while resources below 10 MW are not.

Export to Grid – PDR are compensated only for load reduction and not for energy exported to the grid; exporting to the grid does not make an individual asset or a resource ineligible as PDR, but the resource will not be compensated from the wholesale market for energy discharged to the grid during times in which the resource bids into the wholesale market. Therefore, if there is onsite generation, such as solar PV, that routinely discharges to the grid at any of the sites comprising the resource, this should be considered when deciding when to bid into the market.

Market Products – PDR can participate in both the day-ahead and real-time markets and can provide energy. PDR cannot provide regulation up or regulation down, two of the CAISO's ancillary services. Additionally, PDR can bid into the market to reduce load but not to increase it.

Baseline and Metering – PDR have the option of using baselines or direct metering of generation (or storage) resources to determine load reduction when participating in the market. The baseline methdology uses historic site demand during the hours in which the resource participated in the market to determine if the site(s) provided load reduction compared to the customers' typical load. This topic will be explored in greater detail in the *Metering and Telemetry Report* as part of Task 4: Develop and Pilot Test Technologies and/or Strategies to Lower Cost of Metering and Telemetry.

Dual Participation – Customers participating as PDR are not eligible to participate in utility-administered event-based demand response (DR) programs or from critical peak pricing rates. If customers are currently registered in an event-based DR program or critical peak pricing tariff, they must disenroll before registering with the CAISO as a PDR.

Commercial Barriers to Aggregating DER Portfolio

Portfolio 1

The Portfolio 1 project team identified several commercial barriers while selecting sites for the project. The barriers deal primarily with the value of supply-side DR participation, current PDR rules, and the complexity of the enrollment process. These barriers are described below:

High market rewards appear during relatively few hours that are hard to predict. Given the costs and level of complexity to enroll customers and participate in the wholesale market as PDR, the financial payback for PDRs in the energy market may be small, especially if customers cannot reduce load during

times of higher wholesale electricity prices. The potentially small financial return compared to the complexity and time required for enrollment were concerns for customers.[3]

Limited Benefits of Aggregation for Customers that Export to the Grid – If an aggregated resource has individual sites that export energy to the grid while participating in the wholesale market, then the resource is not compensated for the energy exported to the grid from those sites. Therefore, it is more difficult for customers with onsite generation, such as solar PV, or with relatively small loads compared to the storage system to participate in the market as PDR. Basing settlement payments on an entire resource's energy provided, even if some of the energy was discharged to the grid at individual sites, would allow for sites that export to the grid to more easily participate in the wholesale market as PDR.

Communication and Complexity of Enrollment – Host customers typically require significant communication and education to understand the wholesale market and PDR construct. PDR rules such as non-export and the baseline calculation can be difficult for customers to understand. This requires project developers to have in-house wholesale market expertise and must be able to effectively communicate this with customers. Customer that do not understand the concept, or that are uncomfortable with it, typically do not agree to participate in the wholesale market. However, customers that do agree to participate in the market must go through the enrollment process, which can be complex for both the Demand Response Provider (DRP) and host customer. Streamlining the educational materials available for customers and the enrollment process would greatly reduce the hesitancy of customers to participate in the market.

Dual Participation and Conflicting Programs – Utility-administered DR programs with a fixed capacity payment such as the Demand Response Auction Mechanism (DRAM) are often more lucrative than direct wholesale market participation as a PDR-only resource. Therefore, it can be difficult to enroll customers into the market as PDR if they must disenroll in a DR program or change their utility rate. One benefit of enrolling in PDR is "participation-flexibility" as customers can determine when and how much to bid their capabilities into the energy market, and when to remain out of the market.

Portfolio 2

There are several commercial barriers that the Portfolio 2 project team experienced in selecting sites for PDR participation. The barriers include difficulties extracting the total economic value from the installed technologies, capital investments, contractual limitations and liabilities, and lack of entities with the commercial or technical capabilities to enroll and support DERP/PDR resources in the wholesale market. The commercial barriers associated with Portfolio 2 are outlined below:

[3] PDRs would receive higher returns if they could provide additional services in the wholesale market, such as frequency regulation. This topic is currently being considered by the ISO in the Energy Storage and Distributed Energy Resources (ESDER) Intitiative.

Extracting Total Economic Value - Customers will need to realize the total economic benefits of the installed technologies to offset associated development costs. These upgraded systems will be able to accommodate real time pricing and integrate DER's, but to offset costs these technologies will need additional revenue streams associated with energy efficiency and demand charge management in addition to providing grid services as a PDR.

Capital Investment - Most customers generally do not want to make large up-front investments without having a clear understanding of and confidence in the financial return; therefore, energy solutions which may be offered as a service or based on shared economic performance are desireable. This may cause issues if the project developer does not have the financial resources available to offer a service-based approach, further delaying project implementation.

Contractual Limitations – Generally, commercial building operators and owners do not want to engange in long-term agreements; nor are they concerned about the transfer of liabilities when selling their assets. The project team experienced two cases during the initial site commitment phase in which the potential sale/acquisition of the asset impeded the ability to obtain a firm commitment from the customer.

Ambiguity of the PDR Lifecycle – It is challenging to clearly explain the complete lifecycle of a PDR including the processes of enrolling the resource, bidding the resource, delivering the resource, and settlement of bids. Without an accurate understanding of the business processes of the PDR lifecycle, it is difficult to obtain buy-in from customers and execute contracts.

Lack of Qualified Service Providers - There are few entities with the commercial and/or technical ability to enroll and support PDR in the wholesale market. The project team discovered that this may be due to various business requirements related to the settlements process, lack of awareness and understanding of the resource, limited ability to project financial returns, limited amount of market activity or experience, and few technical solutions capable of integrating resources into CAISO markets.

Technical Barriers to Aggregating DER Portfolio

Portfolio 1

The Portfolio 1 project team identified several technical barriers, described as:

Communication Between Sites and Server – The Portfolio 1 sites will each need to communicate with a central control device which will determine how and when the resources and individual sites should participate in the market. This communication software intelligence is essential to optimize the performance of each site to ensure that sites can participate in the wholesale market while still providing the required services to each customer. One of the major challenges of this project will be to optimize the communication platform and the control and operation of the energy storage systems to achieve the greatest financial payback possible. It may take multiple iterations before the communication and operation of the systems has become optimized.

Forecasting – Forecasting market prices, particularly in the day-ahead market, and onsite customer needs requires developing and implementing intelligent software. While the Portfolio 1 project team has been developing this type of software, other project developers wanting to participate in the wholesale market might not have already developed this type of software. The level of accuracy required to forecast wholesale market prices and onsite customer needs could stand as a significant technical barrier to new market entrants.

Metering – While PDRs may directly meter the onsite generator or storage using the Metering Generator Output (MGO) methodologies, there have been few or no entities to have already used the MGO methodology for PDRs. Therefore, the process of directly metering PDRs and the level of accuracy compared to the traditional 10-in-10 baseline methodology are still unknown. Direct metering for PDRs, which Portfolio 1 may demonstrate, may have unforeseen technical challenges that the project team cannot anticipate in the early stages of developing and installing the metering and data communication protocols.

Portfolio 2

There are several technical barriers that the Portfolio 2 project team has identified related to the technical capabilities of the installed equipment, policies and methodologies of CAISO and the CPUC, and the proprietary nature of technical documentation needed for the integration of revenue-grade technologies. The technical barriers associated with Portfolio 2 are outlined below:

Hardware and Software Integration Issues – Portfolio 2 will install a suite of sensors, software, and controllers to manage the resource. The installed technologies will allow for the management of 10,000's of micro loads based on actual requirements for energy to operate the building per its business reuqirements and occupancy comfort. This extensive suite of installed technologies allows for the risk of data quality issues and hardware malfunctions. The project team will require several technical iterations (i.e. updating software and hardware to new specifications) of the installed technology to achieve the performance characterisitics desired (data quality, volume, speed, etc.).

Ambiguity of the PDR Lifecycle – The ambiguity of the PDR lifecycle provides commercial barriers, as well as technical barriers, for the enrollment of PDRs in Portfolio 2. It is challenging to clearly explain the complete lifecycle of a PDR including the processes of enrolling the resource, bidding the resource, delivering the resource, and settlement of bids. Without an accurate understanding of the business processes and technical requirements of the PDR lifecycle, it is difficult to obtain buy in from customers, execute contracts, and enable market participation for the resources of Portfolio 2.

Technical Requirements from CAISO - Elements of PDR classification and bidding requirements are not clearly addressed in publicly available documentation provided by the CAISO or through other resources. For example, the project team has not found publicly available information related to the implications of enrolling a PDR as a Direct Access customer. If the information is available, it has been difficult for the project team to locate and synthesize it.

Proprietary Technical Documentation - Despite public exposure of technical documentation for participation of PDRs in the wholesale market, existing technical integrations seem to be of a highly proprietary nature and/or modified substantially from the public architecture. Open source projects related to these markets seem to have limited public branches and only provide unstable software which the project team will not generally consider to be of a mission critical or utility revenue grade.

IV. Conclusion

Throughout the customer site selection process, the project team identified several barriers to PDR participation. These barriers can be summarized as:

- Customers are eager for revenue-generating opportunities such as demand response
- There is limited understanding of the risks and economic benefits of PDR participation
- PDR eligibility and enrollment processes are difficult for customers to understand
- Existing PDR rules may be prohibitive for certain types of customers or technologies to enroll or participate as PDR

Developing a central resource that educates and informs customers and project developers of the PDR rules, registration process, market participation and transaction process, and potential economic value would address most of these barriers and be extremely helpful in educating and enrolling customers as PDR into the wholesale market. Additionally, addressing PDR rules regarding exporting to the grid would allow for greater PDR participation for customers and resources that routinely export to the grid, such as customers with onsite solar PV.

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