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Exploration of PG&E Auto DR Incentive Options

Final Project Report

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Energy Technologies Area

December 2017



Exploration of PG&E AutoDR Incentive Options

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Abbreviations and Acronyms

ADR	Automated Demand Response, as used here, refers to standards-based Automated Demand Response
DLC	Direct Load Control
DR	Demand Response
DRAS	Demand Response Automation Server
DRET	Demand Response Emerging Technology
EE	Energy Efficiency
EV	Electric Vehicle
GTA	Global Temperature Adjustment
HVAC	Heating, Ventilation, and Air Conditioning
IEEE	Institute of Electrical and Electronics Engineers
LBNL	Lawrence Berkeley National Laboratory
OpenADR	A standardized, non-proprietary interface that conveys DR signals (e.g., electricity prices or grid reliability indicators) between grid and loads
PCT	Programmable Communicating Thermostat
PG&E	Pacific Gas & Electric Company
SEP	Smart Energy Profile, a set of protocols developed by the Zigbee Alliance
SMB	Small or Medium Business (demand less than 500 kW)
VTN	Virtual Top Node
VEN	Virtual End Node

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EXECUTIVE SUMMARY

PG&E is interested in designing new incentive structures for standards based Automated Demand Response (ADR) control technologies. Specifically:

- PG&E is interested in working with ADR vendors to explore different approaches to developing new channels through which third parties can provide ADR equipment to mass market participants, thereby encouraging broader Demand Response (DR) participation.
- To expand the automated demand response (ADR) program to SMB and residential customers, PG&E would like to know if midstream incentives provided to retailers and distributors or upstream incentives provided to manufacturers are more effective at driving the adoption of ADR-enabled control technologies than current downstream incentives.
- PG&E would like to know if alternate measures for ADR can be developed that may better match ADR Program incentives to desired DR program results.

To help PG&E develop ideas for a DRET pilot to explore these issues, we

1. Reviewed the effectiveness of documented past efforts to change marketing approaches for similar utility programs.
2. Interviewed a wide range of people whose work is related to the provision of DR or energy efficiency (EE) in order to determine their interest in supporting such changes.
3. Analyzed the expected ADR from residential and SMB using physics based models to determine appropriate conversion factors for developing alternate metrics for ADR.

Based on these results, we developed some preliminary ideas for different incentive plans that PG&E can use to test whether upstream or midstream marketing enhances ADR uptake and what alternate measures of ADR performance improve the overall use of ADR within PG&E.

INTRODUCTION AND BACKGROUND

INTRODUCTION

Demand Response programs offer incentives to customers to modify energy use during times of peak demand. There is a growing trend toward automating demand response. The market benefits from the use of common communication standards to facilitate automation because it allows communication and control companies to build technology using common protocols that reduces the cost of integrating ADR technologies into buildings. Common communication standards also allow electricity providers to build common platforms to communicate with customer or aggregator end-use equipment. This report considers strategies for increasing the use of automated DR technology for residential and small and medium business (SMB) customers within the Pacific Gas and Electric (PG&E) service territory.

PG&E is interested in designing new incentive structures for automated DR equipment. In developing these new structures, it is important to understand the incremental cost of the automated demand response (ADR) communication technology. This technology is usually imbedded in end-use controls to communicate with an end-use device. Standards based ADR technologies require that the control system have the ability to communicate using an open standard communication protocol, usually either Open Automated Demand Response (OpenADR, certification for which is available through the OpenADR Alliance) or Smart Energy Profile (SEP 2.0, also known as IEEE 2030.5).

Many of the past PG&E large non-residential ADR projects have used a customer-specific assessment of end-use load control to determine incentives for the ADR technology. Recent ADR programs have paid up to \$200/kW for ADR technology based on the load reduction delivered (Piette et al., 2016). However, this has not yielded the level of demand response (DR) program participation desired.

As a result, PG&E recently proposed (CPUC, 2017b) to focus future efforts in three key areas:

- Noting that the ability of vendors of behind the meter (BTM) technology with the potential to provide DR resources may be limited unless they work through an aggregator or DR provider to enroll the vendor's customers and technology (because they may not have the desire or capability to change their business model to become an aggregator or DR provider themselves), PG&E is interested in working with these vendors to explore different approaches to developing new channels through which third parties can provide ADR enabled control technologies to mass market participants, thereby encouraging broader DR participation.

- Examining how to influence the adoption of “automated DR technologies that use standard open communication protocols” via “incentives to midstream and upstream market actors” via an DRET assessment of the pros and cons of using such channels. These ADR incentives may be more effective than current downstream direct customer incentives. PG&E noted that “as PG&E expands the ADR program to SMB and residential customers, midstream incentives provided to retailers and distributors or upstream incentives provided to manufacturers may be more effective at driving the adoption of ADR-enabled technologies than current downstream incentives provided to customers directly.”
- Identification and evaluation of different ways to calculate ADR incentives besides the traditional \$/kW based on customers’ potential DR load impact.

The goal of this project is to identify strategies to help PG&E evaluate new techniques to facilitate greater adoption of ADR technology that implements common communication standards. This effort will explore possible concepts that could be tested in pilot studies to determine if providing ADR incentives at the upstream or midstream market channels leads to greater levels of adoption of ADR enabled control technologies. Upstream market channels target manufacturers that provide (or embed) the OpenADR VEN¹ at the control technology level. Midstream channels refer to distributors of OpenADR enabled control technology or aggregators of DR services.

BACKGROUND

In the energy efficiency (EE) field, utilities have, for decades, used incentives to encourage their customers to adopt more efficient products and equipment in their buildings. These began as direct payments to end-customers (downstream incentives), but as utility programs have become more sophisticated, they have intervened further up in the supply chain in order to have a larger impact on the market, at lower cost. “Upstream” and “midstream” programs pay incentives directly to manufacturers or distributors, respectively, and are more cost-effective because the same level of incentive payment can be applied to more units of equipment. These upstream and midstream approaches have become common in energy efficiency programs and generally make it easier for utility customers to acquire energy efficient products and equipment.

¹ VEN, or virtual end node, refers to the embedded infrastructure in an end use device to receive DR signals from a VTN, or virtual top node, sender in an OpenADR framework. Typically the VTN is associated with a grid operator or utility.

ADR, on the other hand, requires more than a one-time sale of an efficient product. It also requires an ongoing communication channel with the utility so that the end use device can know when a DR event has been called. In determining appropriate recommended ADR incentive levels, measures of incremental communication costs imposed by DR participation provide the primary reference. These costs necessarily vary based on the communication architecture, since direct, secure communication to a device is different from communicating via a gateway or communications passed through a data cloud. In the latter cases, the costs of verifying secure communication links may be less than communicating directly with a particular device.

To provide a common reference framework, this study focuses primarily on cloud-based ADR communications which is common for residential and SMB customers. Here we use \$200/kW (median cost of over 50 installed automated DR systems) as a benchmark for the costs of OpenADR automation (Piette et al., 2016).

As common illustrative end-use control technologies we consider ADR control of HVAC thermostats, electric vehicles (EVs), residential pool pumps, and behind the meter (BTM) batteries. Additional residential and SMB end-use loads that could be considered in the future include commercial lighting and residential or commercial plug load controls.

METHODOLOGY AND APPROACH

In the work reported here, we used qualitative methods such as interviews as well as quantitative modeling to explore and evaluate new ideas for ADR incentives. Our goal was to develop new concepts for program models to foster greater adoption of ADR technologies for residential and SMB customers. This work is informed, in part, by the DR potential estimation results from California DR Potential Study (Alstone et al., 2016, 2017), including derived estimates of DR potential in the SMB sector. Figure 1 presents the overall research framework and methods used in this study.

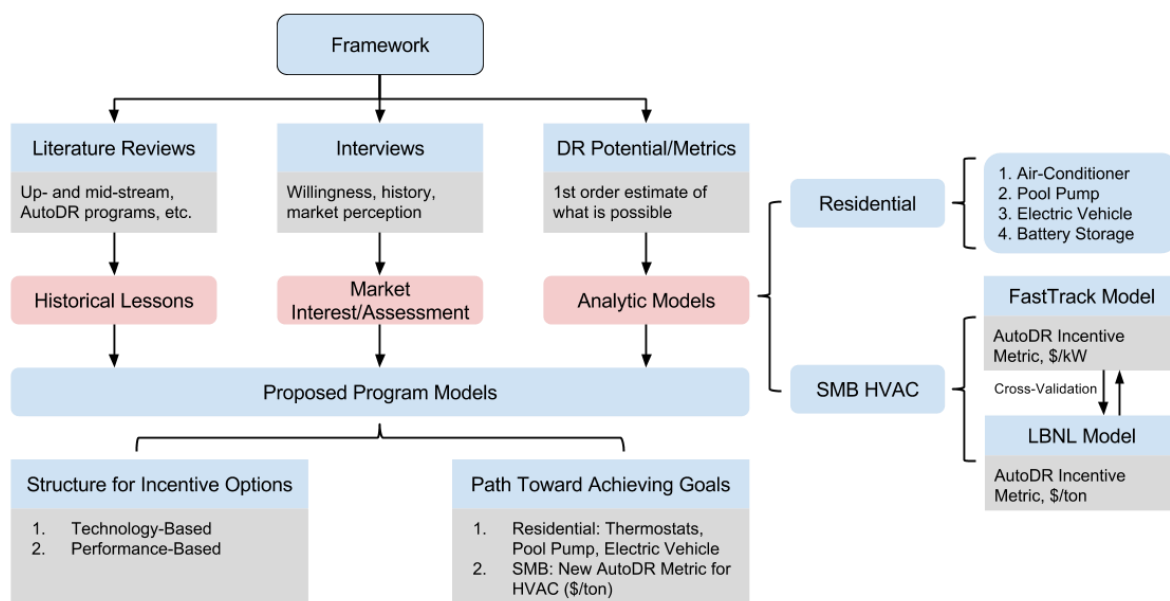


FIGURE 1. OVERALL RESEARCH FRAMEWORK

We began with a literature review to determine what could be learned from previous upstream/midstream marketing of utility programs related to changes in customer use of energy. Next, we conducted a series of interviews with a variety of DR market participants to understand their willingness to participate more directly in customer engagement, market interest, and perceptions about ADR technologies and programs. The interviews covered utility DR program specialists, manufacturers, distributors, suppliers, retailers, and aggregators of OpenADR technologies, as well as those involved with changes related to utility energy efficiency (EE) programs.

To provide quantitative measures for this work, we used existing models to evaluate load reduction potential from residential and SMB customers. We queried the DR Load and DR Path tool from the recent LBNL DR potential study to evaluate what typical peak load reduction values are for several residential end-uses

(Alstone et al., 2017). For the small and medium business (SMB) sector, we used an EnergyPlus model to evaluate possible new ADR incentive metrics. We examined the possibility of paying incentives based on \$/ton for cooling system capacity by using an LBNL DR EnergyPlus model. Finally, we performed a cross-validation of the results derived from the LBNL DR EnergyPlus model against those implied by the FastTrack SMB ADR program. The findings from these activities were distilled into possible structures for incentive payments and paths for moving forward.

LITERATURE REVIEWS

We began by looking at reported changes in market uptake of EE or DR as a result of changes to the market approach. In general, this relies on the following definitions:

- Overall, incentives are typically financial transactions aimed at supporting selected market choices.
- Downstream markets provide incentives directly to the end use customer (consumer). These efforts aim to enhance the acceptance of a product or service that already exists.
- Upstream marketing focuses on ADR product manufacturers. Implementing incentives at this level are believed to influence how the end-users use the product or service by providing more options that have ADR capabilities, and provides a relative competitive advantage to ADR enabled devices through a subsidized price.
- Midstream marketing focuses on distributors, suppliers, retailers, or aggregators of ADR products. Incentives implemented at this stage aim to get the tools into the hands of the consumer and facilitate their participation in the OpenADR market (program, event, etc.).

Because we could find only one study specifically about the upstream/midstream marketing of utility programs for ADR, and its results were preliminary, we also considered the results of work in the related area of EE incentives because of the common focus of encouraging customers to adopt specially designed equipment that allows the end use customer to modify energy use. EE incentive changes to upstream and midstream markets rather than downstream (end-use customers) have resulted in a substantial increase in uptake of EE devices that have translated not only to reduced energy consumption, but also longer lasting products since high energy efficient products usually have a longer measure life.

INTERVIEWS WITH MID- AND UPSTREAM PARTICIPANTS

Historically, the process of signing up for and getting fully enrolled in a ADR program involves a number of steps, each of which provides a point at which end use customers can drop out of the effort (Figure 2):

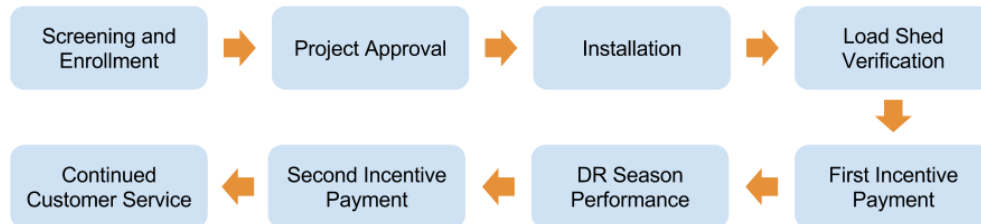


FIGURE 2: AUTO-DR PROJECT MILESTONES

We interviewed typical participants in the various stages of the ADR Program enrollment process to get a sense of the extent to which a change in this process towards mid or upstream marketing of the ADR program might enhance ADR program participation. The interviews focused on what worked (or not) and what each interviewee would be interested to try as a way to increase ADR participation. Regarding to each phase of the Auto-DR project, we designed the following questions for the interview.

Recruitment (prior to sign up)

- What information did you have to make a decision?
- Who did you interact with?
- What influenced your decision to join?

Enrollment

- What was your experience with the enrollment process?

Installation/Enablement

- What equipment (ADR enabled control technology) was installed?
- How disruptive was it?
- Who did the installation and how long did it take?
- Problems and troubleshooting?

Incentive Payment and Settlement

- Willingness and ease of participation?
- Consistency and quality of response?

- Return on investment?

The interviewees included developers, manufacturers, and distributors of ADR equipment (small devices through system developers), two aggregators familiar with PG&E DR programs, a company that installed ADR equipment under the ADR program, a large controls supplier, and a representative from a utility other than PG&E that attempted to enhance its EE efforts through mid- and upstream marketing changes.

MODELING ALTERNATIVE DR METRICS

In 2015, LBNL initiated the California Demand Response Potential Study to explore the role of demand response (DR) in the California electricity market (Alstone et al., 2016). This study evaluated the DR potential for a number of different end uses and technologies across residential, commercial, industrial, and agricultural customer segments. The study described four types of DR services: Shape, Shift, Shed and Shimmy. In this study, we focused on the hot summer Shed service, defined as follows:

- **Shed Service Type is peak hot summer DR:** kW-year. This is the average amount of load shed during the top 250 net load hours. Net load hours are the difference between demand and intermittent renewables. These are hours of the year as when DR is most likely be dispatched.

For the residential sector, the LBNL DR Potential Study considers five residential end-uses, which are HVAC, pool pumps, battery storage, battery electric vehicles, and plug-in hybrid EV. The averaged DR potentials (kW/per unit) for each type of end-use are summarized in the section of results.

A second modeling effort used EnergyPlus energy simulation models to explore potential metrics for ADR incentives. For the SMB sector, as of the date of this study, PG&E offers a "FastTrack" ADR program to streamline the application process on the eligible ADR technologies of HVAC and lighting products. This sub-ADR program pays 100 percent of eligible incentives upon successful inspection and verification of a load shed test based on \$/kW. In this study, we propose a new ADR incentive metric, \$/ton, for use with HVAC based loads. By using this metric, the utility could significantly reduce their ADR implementation efforts by removing the need to verify and measure the performance. Combined with moving incentive distribution to mid- and upstream market chains, ADR uptake is expected to be enhanced.

RESULTS

As noted above, the literature review considered the results of work in the related area of EE incentives because of the common focus of encouraging customers to adopt specially designed equipment that allows the end use customer to modify energy use, and because the successes identified in the EE area were similar to those sought for ADR.

LITERATURE REVIEW

Southern California Edison (SCE) conducted a pilot study of the upstream HVAC with OpenADR during 2013-2014 (Riker, Wang, & Yoo, 2016). The study provided training and incentives to HVAC distributors and contractors to sell & install HVAC roof top unit (RTU) controllers or thermostats with pre-programmed ADR strategies. The ADR incentive was explicitly layered on top of the incentive participants received from the sale of energy efficient HVAC equipment. An additional incentive was available for enrolling customers in DR programs. Early results from this pilot suggest the following strategies are critical to gain customer interest:

- Focus on a short list of eligible OpenADR certified products (prescreened for compatibility with HVAC equipment) so the focus of the effort is on integrating a known solution with equipment and on developing future sales channels.
- Provide a simple, clear value proposition.
- Expand education/outreach to enhance participant and customer knowledge of DR, ADR, and OpenADR (and value it provides).
- Verify HVAC installations to minimize efficiency losses from leaks, oversizing, improper RCA, and mismatched coils.

With the exception of the need to enhance customer understanding of how ADR operates, these strategies were not new: they were also identified for earlier utility EE programs focused improving customer uptake of energy efficiency related products.

In the net-to-gross evaluation of 2013-2014 upstream EE rebates for HVAC programs (CPUC, 2017a), the focus was to encourage distributors to stock and sell high efficiency HVAC equipment. The study evaluated the impact on distributor behavior and indicated how downstream buyers were influenced. It also aimed to distinguish savings from the program vs. free riders. It found that

- (1) 35% of distributor high efficiency stock was in place as a result of the rebate program and this in turn influenced 21% of buyers to acquire that more efficient stock;
- (2) there was 26% distributor upselling (pushing high efficiency equipment because there was an incentive) and this influenced 81% of the buyers;

(3) distributors passed through 54% of the incentive, with buyers indicating the price reduction influenced their choice of equipment.

The study noted, however, that buyers might also be presented with limited options. In some cases, buyers might only see the high efficiency option to which an incentive is attached. In addition, the report noted that uncertainty in how long incentives are available can be a hindrance, as distributors don't want to sell something that has run out of funding. In general, pass through incentives ((3) in the list above) were preferred by both distributors and buyers.

According to one study, customers perceive higher risk with custom (measured/verifiable savings) incentives than with prescriptive or predetermined measures. The latter are considered locked in, so the risk is reduced. This would suggest that most consumers would prefer deemed incentives unless they have a particular operation schedule that might make measured/verified savings worth the effort (Maoz, 2016).

Another study of upstream utility incentive programs examined potential of upstream incentive programs found that they "dramatically increase market penetration of efficient technologies, at a significantly reduced unit cost, compared to downstream incentive programs that directly engage the consumer" (Quaid & Geller, 2014).

This study found that incentive programs can also synergistically increase other resource acquisition. Downsides of downstream incentive programs include:

- contractors not motivated to push more efficient HVAC units because of higher first costs (with lower operating costs, but contractor doesn't benefit from those). Therefore, the units are not typically stocked, and special orders (if consumer wants high efficiency unit) involve delays in getting equipment;
- for HVAC, an estimated 65% of purchases are for emergency replacement units, so energy efficiency is not a big consideration (unless subsidized by incentive).

The study noted that upstream incentives are essentially wholesale price buy-downs. These buy downs can reduce the number of checks the utility needs to write, typically, and no consumer paperwork except to verify purchase. For EE, the per unit incentive can be less since paying for incremental difference at manufacturer or distributor level, and incentive can be reduced by sales volume benefit gained by the seller.

From the perspective of upstream program administrators, another study found that the upstream model works well for energy efficiency programs for large commercial and industrial sectors because of relatively small number of manufacturers and distributors. The goal was to influence a smaller audience who controlled stocking of equipment. A price reduction at the manufacturing level

translates into smaller markups at the wholesale and retail levels. The authors note that for the two end uses studied, in one case (motors) the effort was made obsolete by a change in standards (requiring more efficient motors) whereas in the other case (HVAC) the rebates enabled greater efficiency that utilities could count on, and speculated that it may have also paved the way for the introduction of new technologies such as VRF and water-cooled chillers. This study showed an increase in customer EE participation by a factor of ten, with ancillary benefits of increased customer satisfaction, reduced paperwork, and faster rebates with the change to an upstream market approach. The authors noted that upstream programs are particularly well suited for "replacement on burnout" scenarios in EE. For cyclic loads (refrigeration, HVAC, etc.) upstream programs can be designed to compensate in a more comprehensive way than simple payback that doesn't account well for operating hours (Cornejo & Barnacle, 2013).

A recent Smart Thermostat Incentive program offered by SCE requires that enrollment in this program must be done through an approved service provider. These include Energy Hub, Nest Labs, Venstar Inc., Whisker Labs, or Zen Ecosystems Inc. The program requires a qualified WiFi thermostat connected to a working central air conditioning unit, along with a working Internet connection and residential "bundled service" and an eligible SmartConnect meter. Customers who enroll via an approved service provider between July 6, 2016 and December 31, 2017 (or until available funding is depleted) in the Smart Power Day Incentive Plus program get an initial signing bonus of up to \$125 sign up bill credit per service account (\$75 if an SCE customer; an additional \$50 if also a SoCalGas customer).

Additional bill credits can be earned from 2pm to 6pm on called Save Power Days by comparing actual measured load against a baseline reference developed from the average of the three highest usage days of the previous five non-holiday, non-event days. Bill credits are \$1.25 per kWh reduced. Save Power Days can occur any day of the year, except for nights and weekends. Additionally, customer cannot be enrolled in any demand response program offered by non-utility DR service providers or the critical peak pricing DR program offered by SCE.

A working paper prepared by Nest Labs and Southern California Edison (dated February 17, 2017; not formally published) cites a report ("PG&E Codes and Standards: Home Energy Use Study") that indicates approximately 15% of the installed thermostats in PG&E's service area are manual, with a substantial number of the 85% believed to be programmable thermostats being older than the expected useful life for such devices.

This working paper notes a substantial increase in the number of customers acquiring smart thermostats after the introduction of the incentive program described above, as displayed in Figure 3.

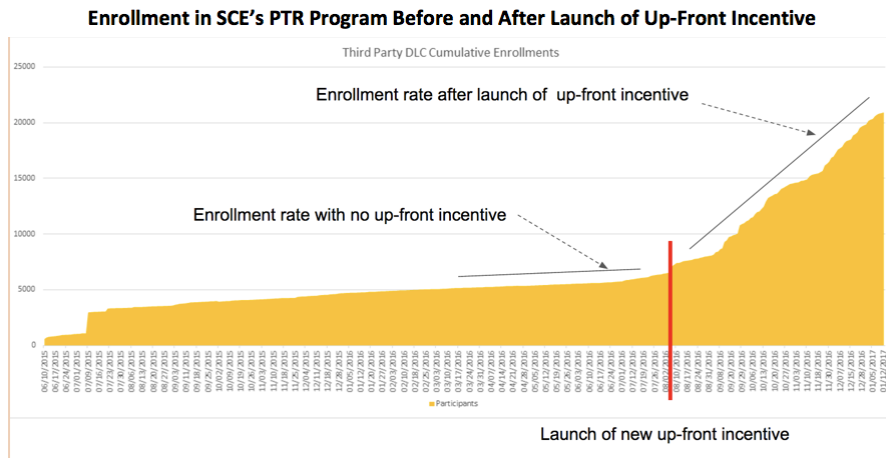


FIGURE 3. INCENTIVES FOR PROGRAMMABLE THERMOSTATS SUBSTANTIALLY INCREASES DR ENROLLMENTS AT SCE

In the first six months of the incentive program, there was a generally increasing trend of new enrollments each month after incentives were introduced (Figure 4):

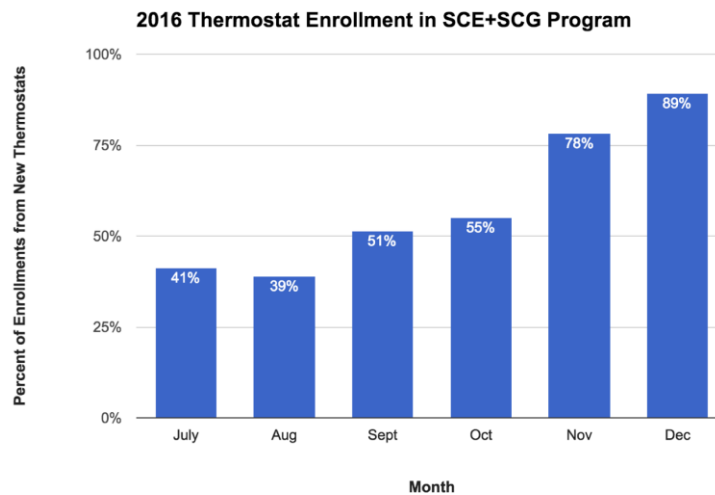


FIGURE 4. DR PROGRAM ENROLLMENTS AT SCE FROM INCENTIVED (NEW) THERMOSTATS

INTERVIEWS

In this study, we completed nine interviews with market participants. Of these, four were manufacturers, two were DR aggregators and two were control vendors. Detailed notes from the interviews are included in this report as Appendix B.

Overall, the interview results suggest that manufacturers and distributors of ADR enabled control technology recognize issues with the existing processes and are eager to become more involved in promoting ADR technology via upstream or midstream incentives. It is noted that the on-going ADR program requires significant involvement from customers on the processes of site audit and load shed verification. As ADR moves from larger customers to the SMB and residential markets, economics may encourage deemed incentives as the load reductions offered by smaller devices may be cost prohibitive to measure individually. The interview results indicate the upstream and midstream ADR incentive option is a very positive solution to foster greater adoption of ADR technologies in the SMB and residential market. Additionally, the cloud-based OpenADR technologies are encouraged to reduce the product hardware cost in association with the OpenADR certification cost.

INTERVIEWEE	MARKET	KEY NOTES
A	Product to facilitate DR	<ul style="list-style-type: none"> Upstream or midstream marketing option (ADR funds to manufacturer or contractor installing equipment) seen as a very positive potential step. Current process requires too much of customers, provides too many places where they can quit or drop the ball. Vendors are more motivated to make the connections
B	Former aggregator of DR in PG&E territory	<ul style="list-style-type: none"> DR value is seen to be shrinking because there are now other resources (e.g. storage) that can respond as (or more) quickly and reliably. Residential segment becomes more likely to be in a position to provide load reductions because of the timing. Funding vendors instead of customers might be OK for HVAC or chiller plants, but lighting is probably too small a load to consider.
C	Manufacturer of control devices	<ul style="list-style-type: none"> Very supportive of the idea of developing upstream incentives for distributors as the dealers could offer something in their toolkit that would generate interest and awareness. As with company A, the sense was that a company that knows the DR programs would be best able to help customers participate more effectively.
D	HVAC manufacturer	<ul style="list-style-type: none"> Advanced HVAC+R ADR rebate (\$350/kW of reduction instead of a standard \$200/kW) from PG&E for a VRV ADR control, which is not on the market yet.
E	Residential equipment using OpenADR	<ul style="list-style-type: none"> The SSL (secure socket layer, a communication requirement) yearly certification for individual devices can be cost prohibitive at small volumes. However, in large volumes (tens of thousands), the

INTERVIEWEE	MARKET	KEY NOTES
		<ul style="list-style-type: none"> annual cost of certification could be negotiated. In the short run, it is generally cheaper and easier to use a cloud OpenADR communication.
F	Large controls supplier	<ul style="list-style-type: none"> The company indicated that only 8-9% of customers have service contracts when asked to consider providing OpenADR and reporting on OpenADR as part of a monthly service contract. Might consider such a service by combining retro-commissioning and DR.
G	Utility outside of CPUC	<ul style="list-style-type: none"> Effort focused on getting more energy efficiency related equipment and devices into the field Utility project managers were responsible for displays and collateral materials in retail outlets. This took considerably more staff time than originally anticipated. In some cases, retailers did not agree that a particular EE capability was of interest to the market, so it was not offered. Overall, direct utility involvement proved cost inefficient, but ultimately did encourage adoption of more EE devices in the field.
H	Thermostat developer	<ul style="list-style-type: none"> The issue of certificate cost for individual thermostats is a real problem. The company processes upstream incentives for energy efficiency programs. Several different mechanisms for processing the incentives: 1) via online store; 2) via third parties; 3) Retail store. This company has never done an upstream incentive for thermostats for DR programs. Usually, the residential DR programs are "bring your own thermostat". This company thinks that the "sweet spot" for incentive level is about \$100/thermostat.
I	Thermostat aggregator	<ul style="list-style-type: none"> Vast majority of thermostat incentive programs are for DR, not EE. The flow of incentive dollars is such that first, an incentive goes to the customer to get their enrollment, then some dollars go to the OEM and the aggregator (shared), and then an ongoing incentive to the customer for participation. Marketing and enrollment are not covered by typical OpenADR utility programs.

DR POTENTIAL ANALYSIS MODELLING

RESIDENTIAL HVAC

Among residential end-uses, HVAC is one of the most promising and commonly used end-use for delivering peak capacity DR when needed. For ADR applications, residential HVAC provides load shed/shift via direct load control (DLC, which is the legacy DR approach) by turning off the compressor for a selected period of time, or via adjustment to the setpoint temperature of a programmable communicating thermostat (PCT). Load shed and load shift potential from residential HVAC vary along with weather conditions, which are especially sensitive to extreme weather events.

Table 1 (data from Alstone et al., 2017) below shows the residential cooling load reduction by climate for representative cities in the DR potential study. The 1 in 2 column refers to an average year whereas the 1 in 10 refers to a hot year across the PG&E territory (note that this may translate to a year with more than usual fog near the San Francisco Bay Area, so the kW shed potential declines in some instances). This demonstrates, for example, that the power reduction for a home in Bakersfield is 0.58 kW in a typical year and 0.71 kW in a hot year. As a reference, a \$200/kW incentive for the ADR thermostat would provide \$116 for a typical year and \$142 for the hot year. But given the cooler weather in Salinas the incentive would only be \$10. PG&E will likely not provide incentives based on climate zones.

Table 1. Estimated Average kW Shed Potential per site from Thermostats in PG&E Territory (from Alstone et al., 2017)

Example City in region	Climate	2020	
		1 in 2	1 in 10
PG&E Average kW shed from thermostats per site		0.33	0.38
Eureka	Cooler	0.01	0.01
San Francisco		0.02	0.02
Salinas		0.05	0.05
Walnut Creek	Bay Area, Mixed	0.22	0.24
Palo Alto		0.15	0.15
Santa Rosa		0.14	0.12
San Rafael		0.13	0.12
San Jose		0.12	0.11
Discovery Bay*	Generally warmer	0.11*	0.13*
Ukiah		0.22	0.28
Grass Valley		0.40	0.47

Yuba City		0.47	0.55
Modesto		0.52	0.60
Redding		0.42	0.50
Fresno		0.61	0.78
Bakersfield		0.58	0.71
*values may reflect data under-sampling for this region			

The DR potential study (Alstone et al., 2017) also evaluated the power reduction from residential pool pumps. For these pumps, the model does not consider the impact of climate variation on power reduction. The study estimated the penetration of pool pumps in residential clusters for each investor owned utility using residential appliance saturation survey (KEMA, 2009) estimates for each IOU. The average pool pump capacity is 0.14 kW (using a conversion factor of \$200/kW, the traditional DR incentive would provide \$28 for an average pool pump). For reference, according to the DR Potential study (Alstone et al., 2017) approximately 9% of PG&E residential customers have a swimming pool with a pool pump. Figure 5 also shows that those pool pumps that operate primarily in the middle of the day.

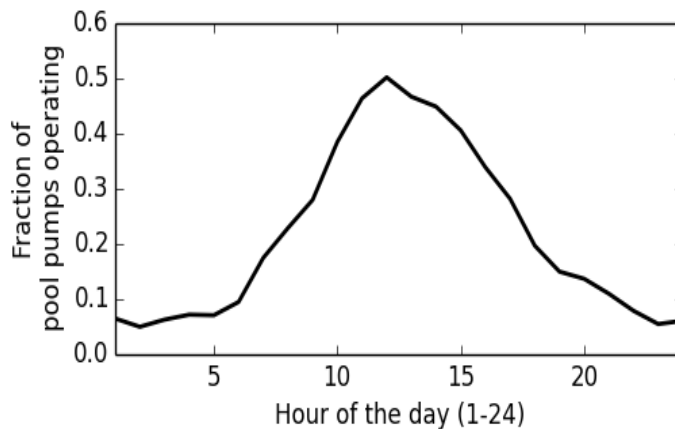


FIGURE 5. ESTIMATED FRACTION OF POOL PUMPS OPERATING BY HOUR OF DAY (SOURCE: ALSTONE ET AL., 2017)

The DR Potential Study used LBNL's Vehicle-to-Grid Simulator (V2G-Sim) to estimate the hourly demand curve associated with future EV adoption. Vehicles were disaggregated as either individually- or commercially-owned using EV rebate data collected from the California Clean Vehicle Rebate Project (CVRP) (CCSE, 2015). Figure 6 shows the predicted 2025 typical weekday average per-vehicle demand for six vehicle-charging categories (see legend), based on an extrapolation from current charging patterns. The average load shed capacity per EV in 2020 and 2025 are 0.52 kW and 0.54 kW, respectively. These values

translate to ADR incentives of around \$106 for an ADR EV charger (based on \$200/kW payment for DR load reduction).

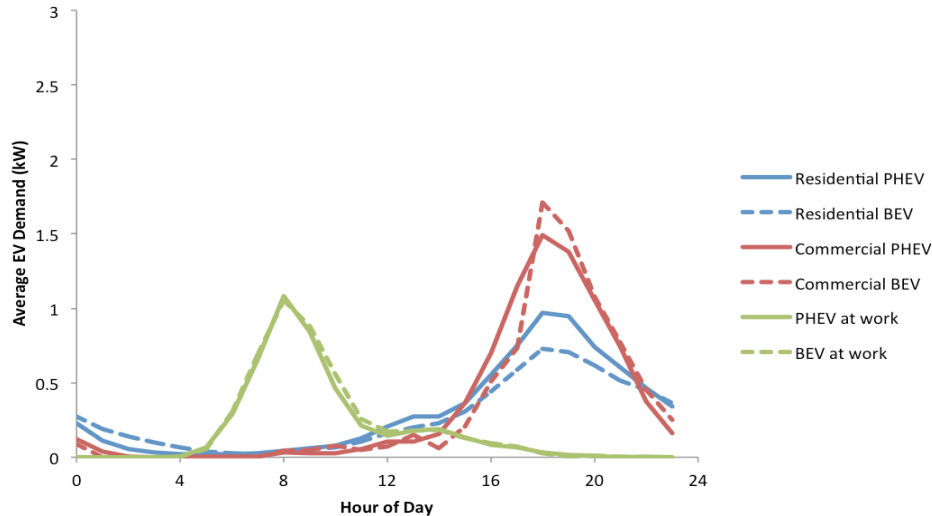


FIGURE 6. ESTIMATED AVERAGE EV DEMAND BY HOUR OF DAY (2025) (SOURCE: ALSTONE ET AL., 2017)

SMALL-MEDIUM BUSINESSES

Historically, ADR incentives have been calculated in dollars per kW shed (\$/kW). The dollar value derived for the conversion factor to develop ADR incentives has been based on costs for ADR hardware and software. The power reduction in kW is the average summer peak day power reduction during a DR event based on the commonly used 10-10 or 3-10 baseline with "Day-Of" adjustment to account for any load variations immediately prior to a DR event.

In order to consider new models for ADR incentives we evaluated several metrics related to DR events, this effort focused on the tons of HVAC capacity for small buildings. We modified reference EnergyPlus models of small and medium commercial buildings to comply with the Title-24 standards (CEC, 2005). The EnergyPlus models include thermal zones, HVAC, and plant models. Small and medium commercial office buildings are equipped with packaged direct expansion (DX) variable air volume (VAV) cooling systems. In the current scope, we simulated these loads in several climate zones. Table 2 shows the results for San Francisco, San Jose, Stockton, and Fresno.

TABLE 2: BUILDING HVAC SYSTEMS IN PROTOTYPE MODELS

Climate Zone	CZ03	CZ04	CZ12	CZ13
City	San Francisco	San Jose	Stockton	Fresno
Building Type	Medium-size Office			
Floor Area	53,628 ft ²			
Peak load (kW)	187	211	235	250
Cooling Peak load (kW)	68	92	112	126
Cooling Power Ratio	0.36	0.43	0.47	0.50
Design Cooling Capacity (tons)	91	97	105	113
HVAC	Air Conditioner Package Unit, COP=3.2			

As a reference year, we choose DR event days in 2015 for the weather data in this study. Each building used an HVAC control strategy of “precool 2 degrees F and reset 4 degrees F” during DR event hours. We estimated electric power shed in kW, HVAC cooling load shed in tons, and coefficient of performance during the event hours, as shown in Figure 7. Notice that HVAC power is saturated when the outside air temperature (OAT) is higher than the design day peak OAT. For all the models developed for this study, the HVAC system is appropriately sized according to the standard sizing factor (ASHRAE, 2016).

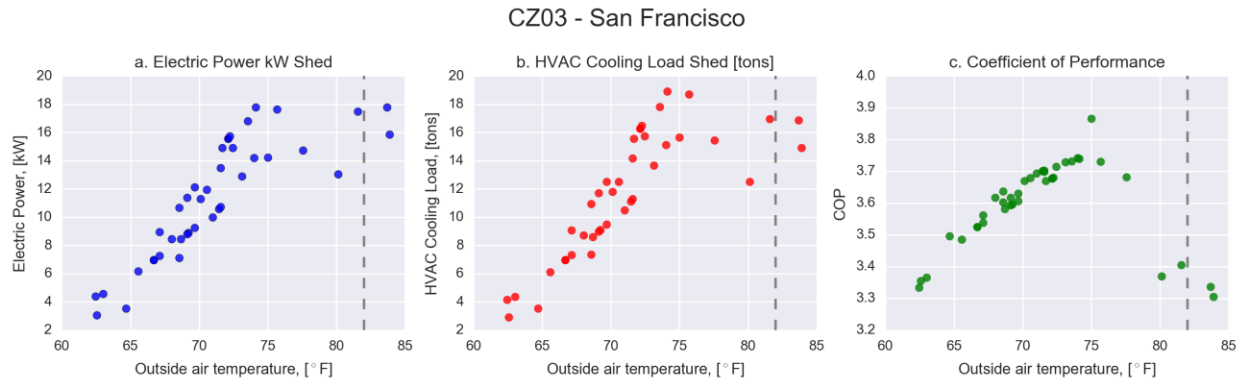


FIGURE 7: MODELLED LOAD SHED AND HVAC PERFORMANCE UNDER DIFFERENT WEATHER CONDITIONS (CZ03)

Figure 7 shows the load shed potential in kW of an example small commercial building at different weather conditions in the CZ03 - San Francisco. It can be seen that the load shed potential increases along with the outside air temperature until the break point, at which the HVAC plant runs nearly at the full capacity. The current ADR incentive is calculated based on the metric of load shed kW. As seen in Figure 7 (a) and (b), the load shed performance in kW can be converted into the cooling tons based on the Equation (1).

$$Q = P \times COP / 3.51685 \quad (1)$$

Where Q is the cooling load in tons, P is the electric power in kW, and COP is the coefficient of performance of the HVAC plant.

In this study, we propose the metric of "\$/ton" instead of "\$/kW" to provide the upstream/midstream incentives to manufacturers. First, we calculate the eligible incentives from the electric power kW shed based on the referenced incentive level of \$200/kW. Then we divide the total incentives by the installed HVAC plant capacity in tons, as presented in the Equation (2).

$$$/ton = P \times (\$200/kW) / Q_{HVAC} \quad (2)$$

Where Q_{HVAC} is the installed cooling capacity in tons.

Figure 8 (a) shows the median and distribution of the incentive "\$/ton" due to the daily OAT variations and (b) shows the average incentive "\$/ton" for each climate zone.

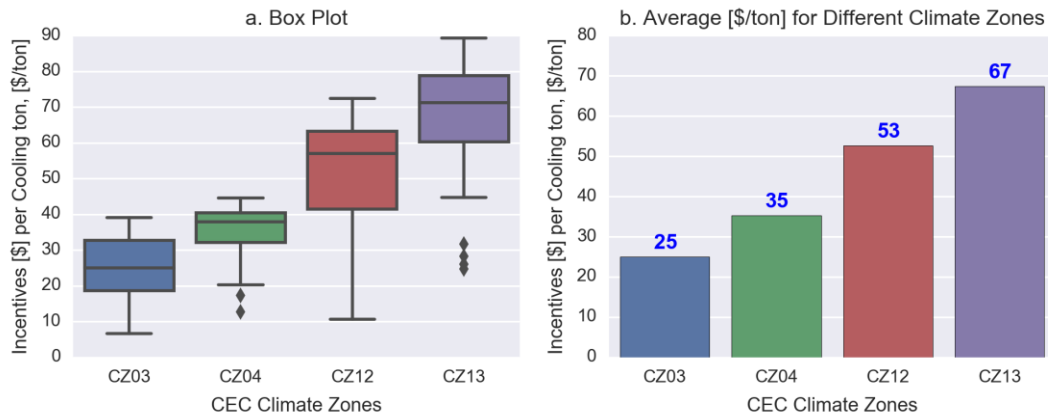


FIGURE 8: INCENTIVES PER COOLING TON FOR AC UNITS AT DIFFERENT CLIMATE ZONES

Table 3 presents a summary of calculated \$/ton effective incentive levels for AC units in different climate zones. This calculation uses the referenced AutoDR incentive of \$200/kW and converts it based on the HVAC performance at each climate zone. This may be a more useful metric because it can be easier to determine the tonnage of a SMB AC system than the peak demand reduction of individual units. This could also be a good strategy for mid- or upstream programs that incentivizes HVAC manufacturers for ADR enabled Smart Thermostats.

TABLE 3: EFFECTIVE \$/TON IN DIFFERENT CALIFORNIA CLIMATE ZONES (REFERENCE INCENTIVE: \$200/kW)

AUTO-DR INCENTIVE LEVEL (\$/kW)	INCENTIVE LEVEL (\$/TON)			
	CZ03	CZ04	CZ12	CZ13
\$200/kW	25	35	53	67

By using the prototype building model, we simulated the same global temperature adjustment ADR control strategy during the DR event hours (2 P.M. to 6 P.M.) of each weekday over the summer season, and calculated the load shed percentage of the whole building power in each DR event hour, as shown in Figure 9. The results represent the typical load shed performance during the DR event hours for a SMB site in hot climate zone (Stockton, CZ12). Then we used the actual meter power data to calculate the average kW shed against each level of the daily peak OAT as shown in Figure 9 (left image). Note that the amount of kW shed increases along with the OAT in the climate zone 12 (Stockton).

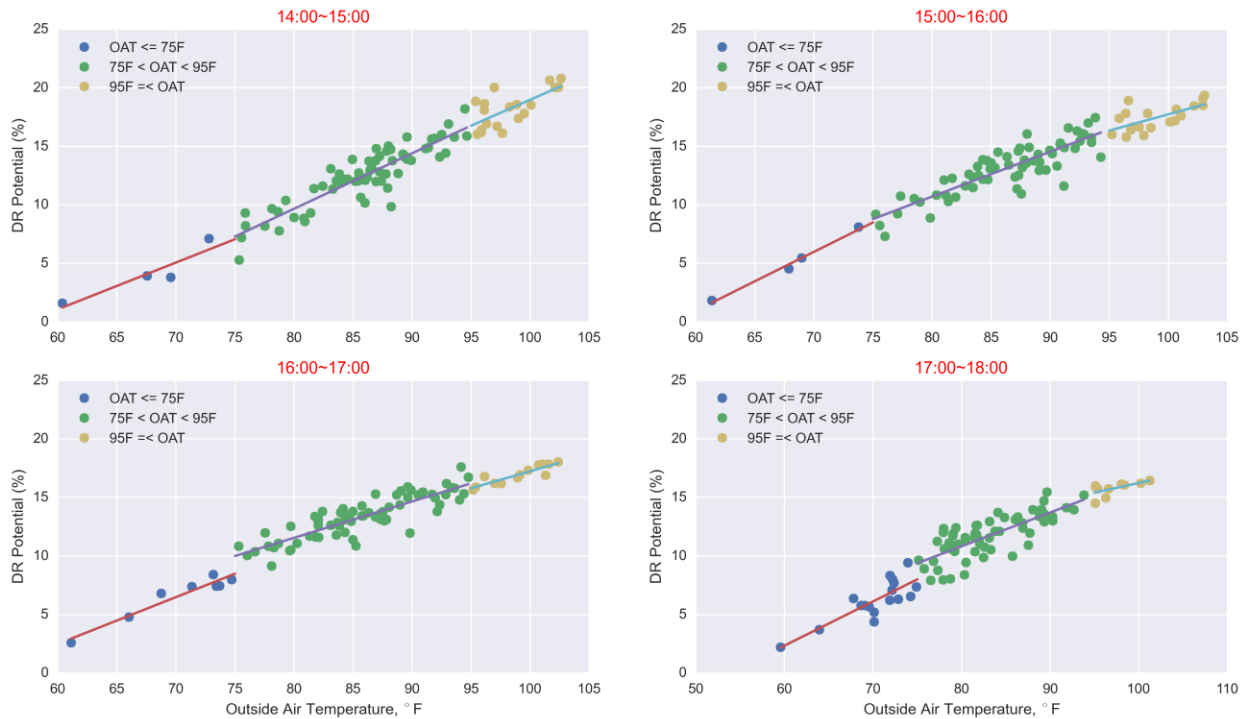


FIGURE 9: PERCENTAGE OF LOAD SHED OVER THE WHOLE BUILDING POWER ON DR EVENT HOURS (CZ12)

We compared the deemed kW savings estimated by the ADR FastTrack program against the values derived by our physics based model (Figure 10 (right image)). Note that the FastTrack kW estimation is very close to the median value of the LBNL model estimate. This suggests that the simplified method used by FastTrack is a reasonable approximation of the savings for these SMB customers. This provides support for the new incentive metric “\$/ton” based on the LBNL model that could be deployed into the upstream HVAC with OpenADR enabled control technologies.

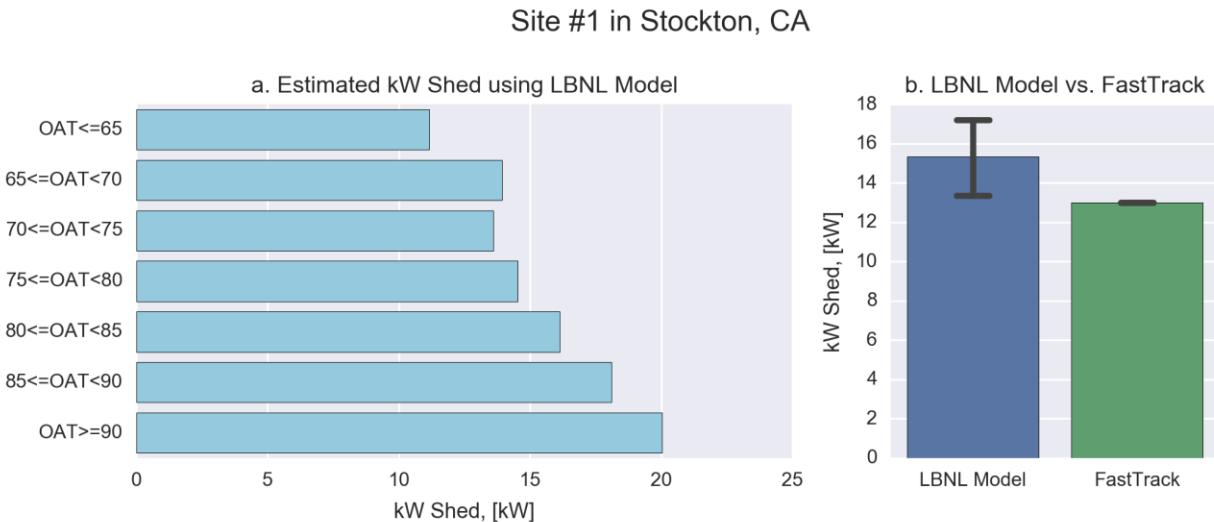


FIGURE 10: COMPARISON OF kW SHED ESTIMATION BETWEEN LBNL MODEL AND FASTTRACK

The single pilot study of the upstream HVAC with OpenADR we were able to identify in the literature (Riker et al., 2016) offered incentives to contractors and distributors based on interviews with three controls contractors, three controls manufacturers, four DRAS manufacturers, two HVAC contractors, four HVAC distributors, and one HVAC manufacturer.

Incentives used in that study were as follows:

Thermostats - contractors only, DR enrollment required in all cases:

- \$150/thermostat if cloud connected
- \$250/thermostat if onsite connected

Unitary AC - incentive offered to contractors and distributors

- \$40/ton if DR enabled
- \$80/ton if DR enabled and enrolled in DR program

VRF - offered to distributors only

- \$2,000 per project if DR enabled
- \$4,000 per project if DR enabled and enrolled in DR program

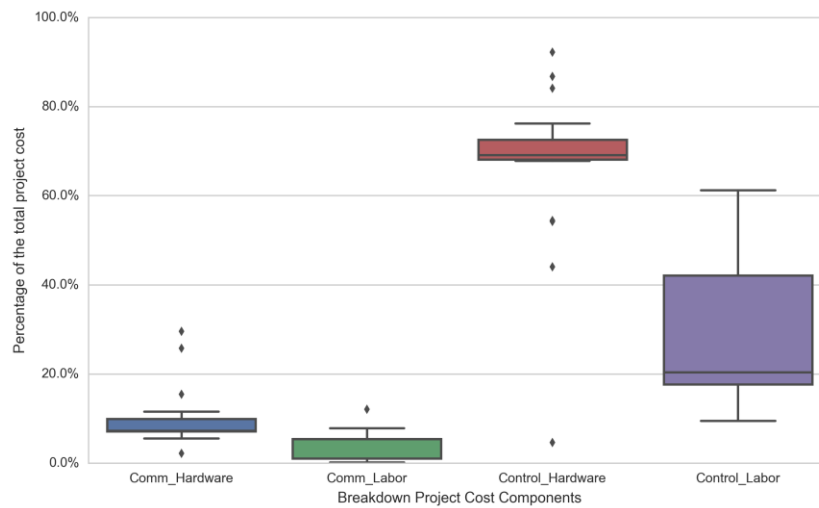
These derived costs per ton are remarkably similar to the results derived in our work using locational modeling starting with a \$200/kW ADR incentive.

ADR ENABLING COSTS IN MEDIUM AND LARGE COMMERCIAL BUILDINGS

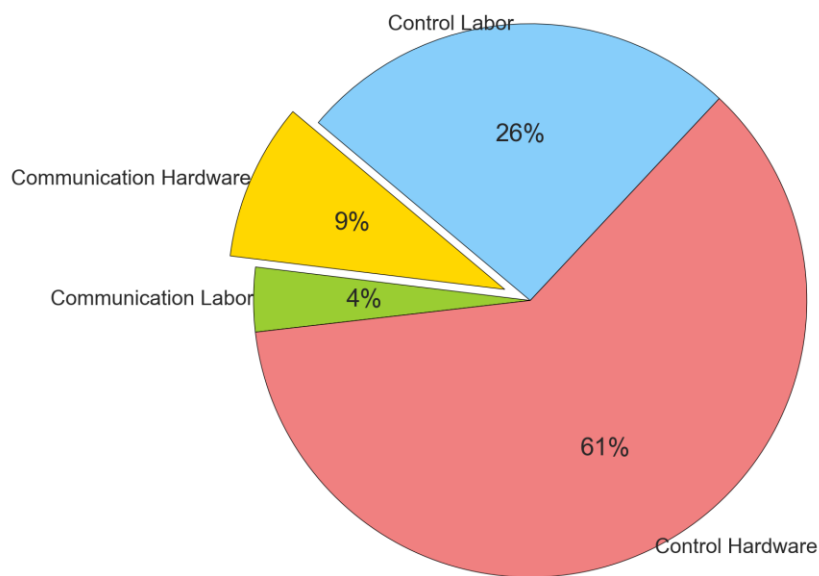
(Piette et al., 2016) reported on the actual costs to integrate commercial buildings with the grid through auto demand response. Their study compares cost data from several ADR programs and pilot projects and evaluates trends in the cost per unit of ADR and kW available from automated systems. It is summarized that the median costs for the surveyed automated DR systems are in the range of \$200/kW.

In this study, we analyze the breakdown cost for ADR systems installed in medium and large commercial sectors (office, retail, theater, restaurant, government, etc.) by the portion of communication hardware & labor cost, control system hardware & labor costs. Such costs are critical to determine the value of ADR in different markets. We collected nearly 50 commercial buildings' ADR project cost data between 2013 and 2016.

Figure 11 shows the distribution of ratio of communication (a) distribution (up) (b) average (down) costs of each component (communication hardware & labor, control system hardware & labor) in percentage over the total project cost. Relative to the communication component in the system, more than half of the projects' communication hardware cost is less than 10%, as well as for labor cost of communication device installation. The average cost of the communication hardware is about 9% of the total ADR project cost. It is clear that the control system hardware and programming ADR actions accounts for a large portion of the project cost. Additionally, it is interesting to see the portion of control system labor cost varies with each project. This result indicates the variable cost of ADR management system is largely caused by the system complexity.



(a)



(b)

FIGURE 11: (A) DISTRIBUTION AND (B) AVERAGE OF THE PERCENTAGE OF THE TOTAL ADR COST BY EACH COMPONENT

Discussion and Conclusions

INCENTIVE OPTIONS

Following the interviews and discussions with PG&E about ADR incentives for residential and SMB customers, we developed a set of concepts that could be considered in potential pilot programs. We propose several variations of technology- options for manufacturers, and aggregators separately, as shown in Figure 12.

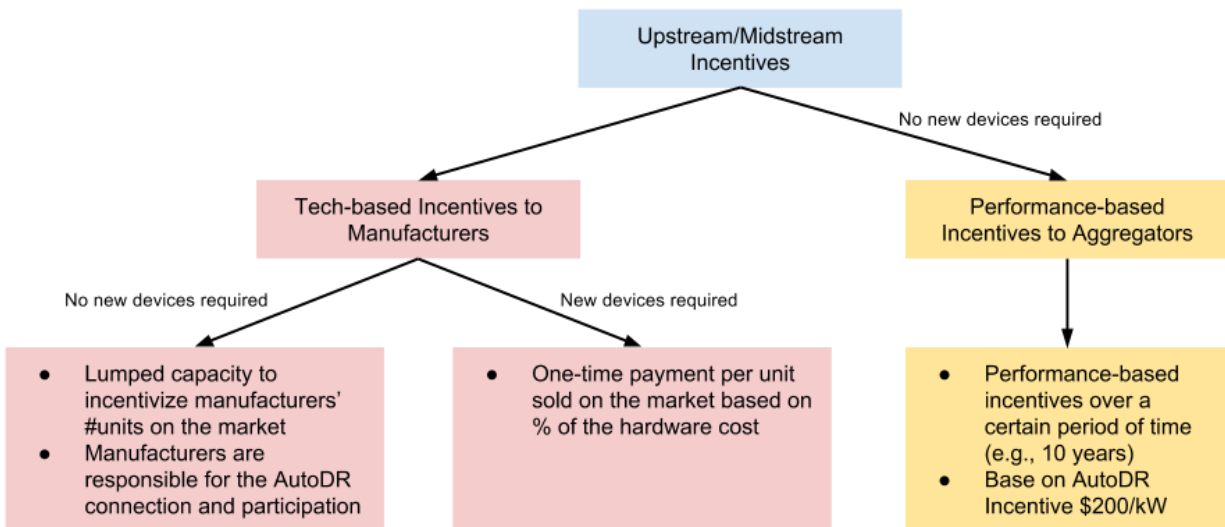


FIGURE 12: LOGISTIC MODELS FOR UPSTREAM/MIDSTREAM INCENTIVE PROGRAM

TECHNOLOGY BASED OPTIONS

Technology-based incentives set the financial incentive level according to the technical specifications of the ADR-enabled control technologies (e.g., for a communicating residential smart thermostat that is certified to work with a standard communication protocol). In this scheme, manufacturers or distributors would receive incentives when they confirm they have enrolled customers in DR programs using ADR enabled control technologies that meet the technology specifications. Those incentives could be passed on to the end customer in whole or in part by the manufacturer or distributor either via reduced cost equipment or as a direct payment.

Based on interview results, manufacturers note that they need to be familiar with DR program details in order to design their products, and those interviewed indicated this would be a welcome development. Two options are possible:

- New devices - one time payment based on % of hardware cost
- Any device - based on volume (# of units participating)

Tables 4 and 5 present proposed options for technology-based incentive program options for thermostats and EVs, respectively.

TABLE 4: TECHNOLOGY-BASED INCENTIVE PROGRAM FOR THERMOSTAT

Market Intervention Point	Goal	Plan	Why
Upstream	Volume rebate to reduce cost to end user	Provide bulk incentive, tiered to get more units with OpenADR certified capability into the market. Requires confirmation of at least ~80% installed and operating in PG&E served area	Costs to install OpenADR are only partly the marginal per unit cost. Some of the cost may be related to developing a cloud interface that benefits all units. Incentive might encourage a more focused effort.
Midstream	Distributor incentive packages to get more devices into the market.	Sales bonuses based loosely on proposed structure for upstream.	Encourage more sales with higher incentives for selling more devices. Incentive payment could be tied to confirmation of enrollment in DR program
Contractor	Education and incentive for units installed and enrolled to get more into residences and SMB.	Online OADR connection class. Once certified, get rebate on each installed unit	Want to make sure device is connected properly, so incentive could be tied to confirmation of ping to VTN (DRAS)
Notes: Assumption: individual thermostats connect to utility based VTN ² (DRAS) via cloud, not individual certificates			

² VTN, or virtual top node, is the portion of OpenADR that conveys utility or aggregator originating price or grid stability signals to VENs (virtual end nodes) embedded in end use devices, where the signals are interpreted and converted to load reductions according to location dependent previously established rules. DRAS is the demand response automation server that hosts the VTN.

TABLE 5: TECHNOLOGY-BASED INCENTIVE FOR EV CHARGING STATIONS

Market Intervention Point	Goal	Plan	Why
Upstream	Commercial charging stations: Volume rebate to reduce cost to end user Residential customers: rebate to reduce cost	Provide manufacturers \$100 for each charging station (L2).	Previous offer \$400 rebate for participating remote charging program (Kalaza et al., 2017)
Midstream	Distributor package includes the setup of connection to the cloud.	No credits	Easy setup by following the instruction.
Contractor	Contractor installation package includes the setup of connection to the cloud.	No credits	Step by step instruction manual (flat installation cost \$850), cover the connection setup easily.
Notes: 1. Cost breakdown. Labor: expect to pay an electrician or contractor about \$500 total for the entire installation process, with an hourly fee of \$65-\$85 per hour. Materials: there is a wide variety of EV charging station options available at all price points, but the average station costs \$600-\$700.(Smith & Castellano, 2015) 2. Assumption: individual charging station connect to VTN (DRAS) via cloud, not individual certificates 3. Use load impact instead of purchase price to calculate incentive so that incentive compensates for value delivered, not the original cost.			

PERFORMANCE-BASED OPTIONS

Another option for providing incentives for standards-based ADR capabilities is what we call "performance-based" incentives. This approach bases the amount of incentive payment on the actual DR performance in program events using the ADR technology, making it an "ex post" approach where the technology incentive payment is made after the technology is sold, installed, and participates in DR events. Performance-based incentives would most easily be implemented through DR aggregators, both to reduce transaction costs and because the aggregators have the event performance data for their end-customer subscribers, which is essential for determining the incentive value.

Figure 13 shows proposed incentives for performance-based incentives to aggregators, based on an assumed \$200/kW as a benchmark for the costs of OpenADR automation (Piette et al., 2016). It is assumed that the performance-based program will last 10 years. The amount of ADR incentives after the initial payment will be \$5-10 per year awarded annually. As part of communication enablement cost, which is the one-time payment for ADR cloud service, we

assumed a maximum of \$10K to build a cloud VEN client to receive the utility's OpenADR signal.

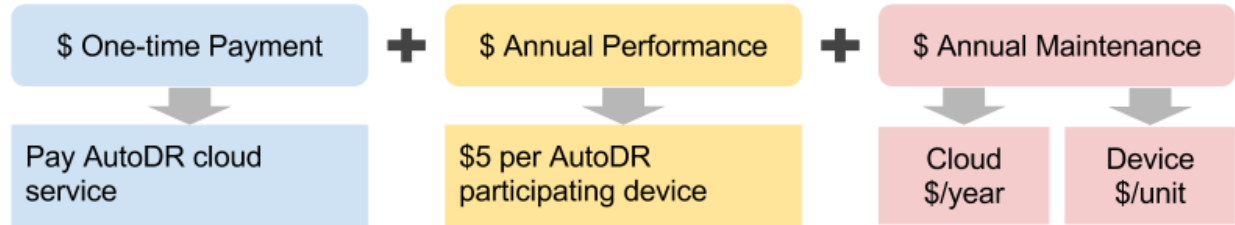


FIGURE 13: PERFORMANCE-BASED INCENTIVES TO AGGREGATORS

This approach assumes the cloud-based DR event communication architecture shown in Figure 14.

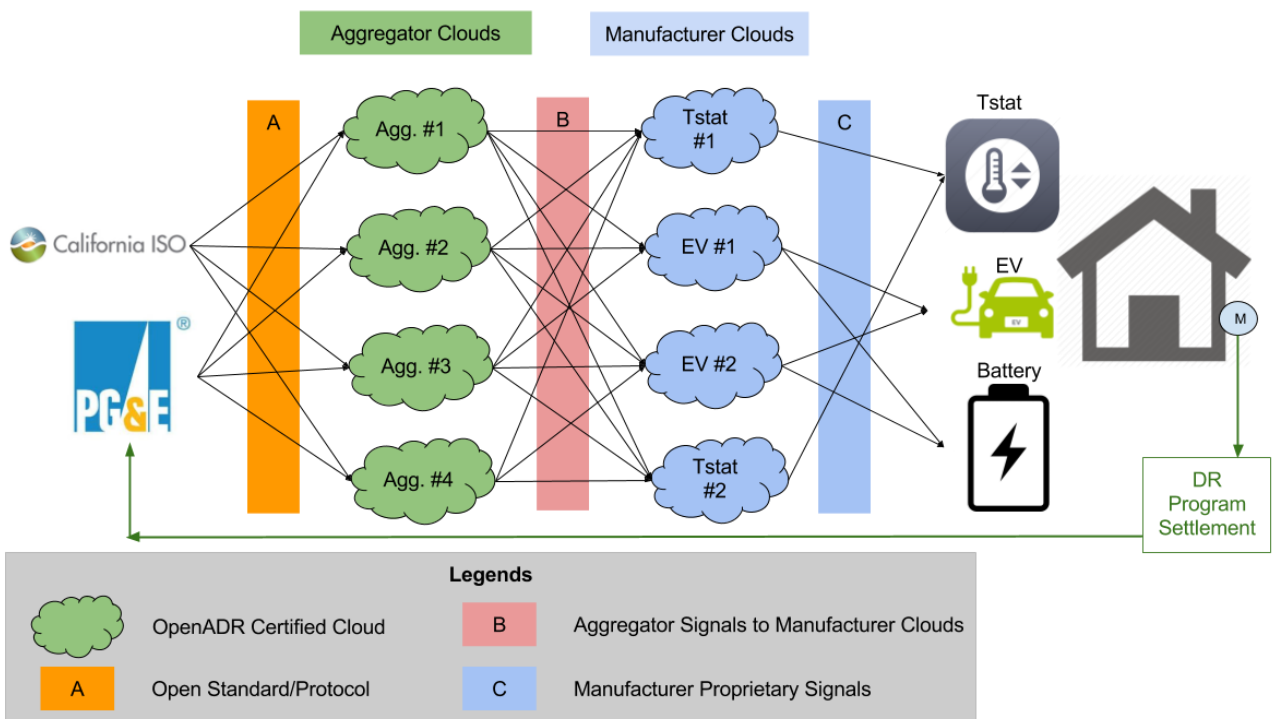


FIGURE 14: DR COMMUNICATION ARCHITECTURE SHOWING MESSAGE FLOW BETWEEN AGGREGATOR AND MANUFACTURER CLOUDS

In this communication architecture, the standards-based DR event signals are first sent from PG&E or CAISO through the Internet to a DR aggregator's cloud-based communication interface (e.g., their OpenADR VEN). The signals are then relayed over the Internet to a product manufacturer's cloud management interface, e.g., the cloud-based APIs for a connected

thermostat manufacturer. The manufacturer then relays the signal to the requested devices in specific customers' buildings. At some point along this path, the DR event signals from the grid operators are translated into control commands for specific devices. For instance, the DR signal that "Program Y is calling an event" needs to be translated into a control command, such as "raise the thermostat setpoint for Customer Z by four degrees." These message translations can be performed by the aggregator or the manufacturer, and would involve translation to either a vendor-specific proprietary protocol or an open standard (typically BACnet) downstream from the translation point. Generally speaking, the number of actors in each "tier" of communication increases as the signals propagate from left to right in Figure 14. Roughly speaking, there are two "grid operators" in Northern California (CAISO, operating at the larger regional level while coordinating independent operators, and PG&E focusing on operations more locally in coordination with CAISO), a small number of aggregators, tens of device manufacturers, and potentially millions of devices in buildings. The advantage of this architecture, and the concept of ADR aggregators in general, is that the aggregators hide the complexity of dealing with many types of devices at a large number of customer sites, by presenting a consistent, simplified interface to the grid DR operators. It should also be noted that the architecture shown in the diagram does not require that the aggregator communicate downstream with a manufacturer cloud. The aggregator could also communicate directly to a gateway in the building, or directly to end-use device(s).

Implicit in this architecture is an assumption that the aggregator has an ongoing relationship with the grid DR operator and acts as an intermediary both for forwarding DR event signals and for relaying event settlement information back to the grid DR operator. This has two benefits: 1) aggregators can be incented on an ongoing basis for the performance of the devices they control because of their continuing involvement in DR event implementation, and 2) aggregators have the data needed to determine performance-based ADR technology incentive payments because of their role in ADR event settlement. The aggregator-based communication architecture has two technical benefits as well: 1) the standards-based communication protocol required by the grid DR operators for interoperability only needs to be received by a handful of aggregators, which simplifies the integration process, and 2) integrating a new manufacturer or device type into the architecture does not change anything with the signals between the grid and the aggregator – all the integration effort is downstream from the aggregator cloud. When an aggregator integrates a new device manufacturer into this architecture, it not only enables ADR communication with new devices sold in the future, but it also brings along with it that manufacturer's existing devices in the field that are connected to its manufacturer cloud. In this way,

this performance-based approach can be used to bring both new and existing connected devices into the grid operator's standards-based DR programs.

To implement this performance-based program, the grid DR operator would sign a technology incentive contract with qualified DR aggregators, which would spell out several factors:

- How much the incentive payment is per program period (this could be settled annually at the end of either the program or calendar year, although monthly payments could also be possible if the administrative overhead were acceptable),
- How many years the contract is in force (probably between two and ten years, based on typical lifetimes for DR automation equipment),
- The threshold level of DR event performance from each participating customer (e.g., a minimum amount of load shed per event, or an average over all events in the season, etc.),
- Whether the incentive is a fixed amount paid if the customer exceeds the threshold, or pro-rated based on the level of performance,
- Whether the incentive is paid on a per-customer basis or on a "fleet average" basis for all the participating customers in their portfolio (similar to the CAFE standards for vehicle fuel economy).

To illustrate how this incentive system would work, consider the following example of a residential communicating thermostat (Table 6). A typical price for these products is around \$200, with an assumed lifetime of 10 years. If the program implementer were to simply pay back the purchase price over the life of the product, the annual incentive would be \$20. If an individual thermostat performed as expected (i.e., met the DR performance threshold) every year of its life, then the aggregator would recoup their investment over the ten years. However, this does not account for the time value of money or the performance risk that the aggregator assumes. To account for these factors, consider a simple present-value analysis shown in Table 6, which demonstrates that the \$20/year payment over 10 years actually has a present value of between \$120 to \$170. The discount rate can be interpreted as the amount of risk that the investor (i.e., the aggregator) assumes in their investment. The lower discount rate probably only includes the time value of money, while the higher value might include other forms of risk such as performance risk. It is possible that, depending on their view of the incentive risk, the aggregators may even require a 20% to 40% return on their investment, implying that they want to recoup their initial investment within 2-4 years.

TABLE 6: FINANCIAL CALCULATIONS FOR MID/UPSTREAM INCENTIVE PAYMENTS

Term (years)	3	5				10			
Annual incentive (per year)	\$50	\$10	\$20	\$30	\$50	\$10	\$20	\$30	\$50
Total incentive cost	\$150	\$50	\$100	\$150	\$250	\$100	\$200	\$300	\$500
Net present value (% discount rate)									
Aggregator (10%)	\$124	\$38	\$76	\$114	\$190	\$61	\$123	\$184	\$307
Utility (3%)	\$141	\$46	\$92	\$137	\$229	\$85	\$171	\$256	\$427

The performance-based incentive approach has several benefits and drawbacks. First, on the positive side, this program design:

1. Transfers the technology performance risk from the grid DR operator (i.e., the ratepayers) to the aggregator or customer, including "technology obsolescence" risk that a given DR automation technology will become obsolete (or the vendor go out of business) after only a year or two;
2. Diversifies the performance risk across an entire portfolio of participating customers;
3. Reduces transaction costs compared to a downstream program that pays incentives to individual customers or retailers;
4. Could allow customers to seamlessly "re-enter" the program even if they don't meet the performance threshold in a given year;
5. Avoids "double payment" for multiple DR automation technologies installed at a single customer site, as long as the incentive is proportional to the DR performance measured at the customer whole-building meter rather than the device level;
6. Provides an incentive for existing devices installed in the field to be enrolled in a DR program.

On the negative side, this program design:

1. Requires that aggregators be pre-qualified to participate in the program, which serves as a barrier to participation;
2. May require higher incentive payments to aggregators because they are bearing the technology performance risk and also the time risk of receiving their incentive payments spread out over time;
3. May confuse aggregators about the role of technology incentives vs. event performance incentives, because both types of incentives would now be paid ex-post based on event performance (i.e., could the technology and event payments simply be combined into one incentive?);
4. The incentives may encourage more enrollment of existing devices rather than installation of new devices, in order to minimize

aggregator capital outlay for buying new customer-sited automation equipment.

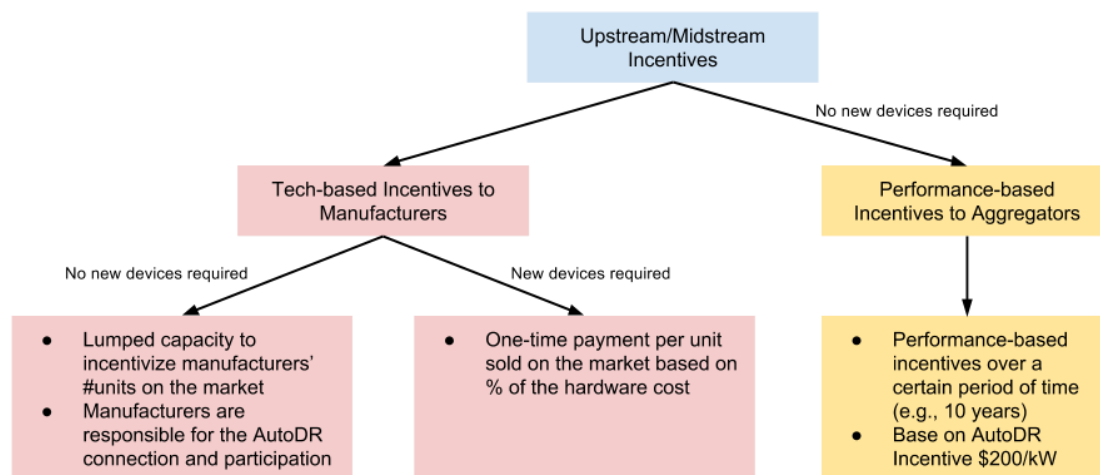
FUTURE DIRECTIONS

This study has explored a variety of models and cost data for PG&E to consider in exploring how to offer incentives for ADR systems for residential and SMB customers. We provided examples of previous considerations of mid- and up-stream energy efficiency and ADR incentive programs that show promise in providing new market channels for ADR incentives.

We also provided a number of quantitative benchmarks for the residential and SMB peak demand reduction values and compared them with typical values for a \$200/kW baseline ADR incentive.

It is useful to revisit Figure 12 (repeated here below) because it summarizes a framework PG&E may want to consider further investment in.

Manufacturers or distributors could be paid for connected devices to their OpenADR certified cloud, which means that manufacturers would be responsible for the ADR enablement from the cloud to the connected devices. Additional one-time payments per unit could be offered for new devices, based on a certain percentage of the hardware cost. PG&E could pay upstream manufacturers that have DR resources on the market based on the amount connected devices (with a sliding scale, as illustrated in the examples provided earlier, to encourage the placement of more devices into the market).



The success of these ADR incentive models will be based on the opportunities to partner with ADR technology manufacturers, developers, distributor and aggregators. Interview results and literature review suggest that this could be a promising new approach to get more ADR enable control technologies enrolled and active within the PG&E territory. The cloud-based ADR technologies are encouraged to make more cost effectiveness in particular for SMB and residential customers. Therefore, in the future, manufacturers/vendors are going to play more roles in the ADR market, as well as aggregators.

In particular for the ADR incentive to HVAC units in SMB sector, we proposed a new ADR incentive metric "\$/ton" for upstream incentives to HVAC manufacturers. The advantage of using this metric is that the entire process of ADR customer recruitment, performance verification, and incentive settlement can be significantly simplified. The EnergyPlus models also showed that future ADR incentives could be based on the size of the cooling tonnage of an AC system for SMB customers. This encourages the adoption of ADR enabled control technologies in the market through the upfront upstream incentive payment option. For this approach, we also found the ADR FastTrack DR load reduction levels are similar to the LBNL EnergyPlus model predictions, so these results support the robustness of that program.

REFERENCES

- Alstone, P., Potter, J., Piette, M. A., Schwartz, P., Berger, M. A., Dunn, L. N., ... Jain, A. (2017). *Final Report on Phase 2 Results - 2025 California Demand Response Potential Study*.
- Alstone, P., Potter, J., Piette, M. A., Schwartz, P., Berger, M. A., Dunn, L. N., ... Szinai, J. (2016). *Final Report on Phase 2 Results - 2015 California Demand Response Potential Study*. Lawrence Berkeley National Laboratory.
- ASHRAE. (2016). *ANSI/ASHRAE/IES Standard 90.1-2016 -- Energy Standard for Buildings Except Low-Rise Residential Buildings*. Retrieved from <https://www.ashrae.org/resources--publications/bookstore/standard-90-1>
- CEC. (2005). *2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. Retrieved from <http://www.energy.ca.gov/title24/2016standards/index.html>
- Cornejo, D., & Barnacle, B. (2013). The 900 Percent Solution Upstream Best Practices across HVAC and Multiple Technologies. In *International Energy Program Evaluation Conference: IEPEC*. Chicago, IL. Retrieved from <http://aesplibrary.conferencespot.org/58584-aesp-2013-1.3428356/t-002-1.3428734/f-002-1.3428735/a-077-1.3428762?qr=1>
- CPUC. (2017). *Net-to-gross Evaluation of 2013-14 Upstream HVAC Programs (HVAC1)*. Retrieved from www.dnvgl.com/energy
- KEMA. (2009). *2009 Residential Appliance Saturation Study*. Retrieved from <http://www.energy.ca.gov/appliances/rass/>
- Maoz, K. (2016). To deem or not to deem? That is the (valid) question. Retrieved December 11, 2017, from <https://blogs.dnvgl.com/energy/to-deem-or-not-to-deem-that-is-the-valid-question>
- Piette, M. A., Black, D., & Yin, R. (2016). Comparison of Actual Costs to Integrate Commercial Buildings with the Grid. In *2016 ACEEE Summer Study on Energy Efficiency in Buildings* (pp. 1-12).
- Quaid, M., & Geller, H. (2014). *Upstream Utility Incentive Programs: Experience and Lessons Learned*. Retrieved from http://www.swenergy.org/data/sites/1/media/documents/publications/documents/Upstream_Utility_Incentive_Programs_05-2014.pdf
- Riker, C., Wang, K., & Yoo, F. (2016). Energy Efficiency and Automated Demand Response Program Integration: Time for a Paradigm Shift. In *ACEEE Summer Study on Energy Efficiency in Buildings*. Pacific Grove, CA. Retrieved from https://energy-solution.com/wp-content/uploads/2016/10/ACEEE-EEandADR_Riker_Wang_Yoo.pdf
- Smith, M., & Castellano, J. (2015). *Costs Associated With Non-Residential Electric Vehicle Supply Equipment*. Retrieved from https://www.afdc.energy.gov/uploads/publication/evse_cost_report_2015.pdf

APPENDICES

APPENDIX A: INTERVIEW NOTES

Company A – Product to facilitate DR

Summary: Upstream or midstream marketing option (ADR funds to manufacturer or contractor installing equipment) seen as a very positive potential step. Current process requires too much of customers, provides too many places where they can quit or drop the ball. Vendors are more motivated to make the connections.

Noted that many customers expect some physical reward for reducing usage: could be price reduction that they can explicitly see at the time, a line item on a bill showing a reimbursement or an incentive, or a physical check. This is important to customers.

Noted that during M&V, there is an expectation on all parts (installer and customer) that performance will be good.

Regardless of change in marketing strategy, the onus will still be on the participant to do a committed response. This could be via a vendor holdback of incentive at the end of the first DR season. Key is to make sure vendor not seen as bad guy in this so need to be explicit about flow of funds from utility to vendor and what is needed to achieve reimbursement for participation.

Noted that part of the problem with incentives is the time it takes - right now the vendor has to wait until the customer gets reimbursed to be paid themselves. They build this into their market approach, but it means upfront funding on their part to get equipment installed prior to reimbursement from customer (using funds from IOU reimbursement). Thus, upstream or midstream marketing seen as faster reimbursement to vendor.

Cited analogy with marketing strategy for leasing Nissan Leaf EVs: while buyer can't claim federal incentive because it goes to Nissan Leasing, they show how it helps reduce the lease payments. Further, they show how the state incentive (which customers can claim by registering) essentially pays for down payment and first two years' lease payments. Explicitly showing the cash flow helps customers decide to make the sale (initiate the lease).

To sell [this product] for EE, they say here's the price and here's your expected savings. DR sales are on top of that ("DR incentives are just icing on the cake") - noted it is very hard to lead with DR, so they don't do it. They only promote it on top of EE. Customers get bigger savings in EE without noticing any changes.

Noted that some national chains won't even try DR because of cash flow issues (need to install and get M&V before getting first payment.).

Noted that in general customers rarely know about DR programs because most don't go actively looking for them. However, they expect vendors to know about DR programs, particularly if they are marketing in that area. So, it makes sense to put the incentives with the vendors, then require vendors to prove equipment is installed, online, and functioning, AND to prove that customers signed up for a DR program before they get the incentive from the utility. They can then use the incentives in a transparent way to motivate the customer to sign up for DR programs. They can help with this process, then provide OpenADR via the cloud. The technician sets up the online connection during the installation.

Noted the value of cooling for them is \$20/Ton for EE, could be raised to \$40/T if DR added.

Company B – Former aggregator of DR in PG&E territory

DR value is seen to be shrinking because there are now other resources (e.g. storage) that can respond as (or more) quickly and reliably. BYOT programs offer technology that can respond 20 times in a day without occupants noticing.

When DR events were typically in the middle of the day, then large C&I could provide appropriate response. But with a shift in those hours towards later in the day, residential segment becomes more likely to be in a position to provide load reductions because of the timing.

Noted that their customers prefer shorter events - four hour events are just too hard to maintain for most customers. Commented that storage is more reliable, faster, and dispatchable, and can respond at \$60/kW. Also, storage can be aggregated to provide load reductions of whatever size is specified. By contrast, most other DR is seen as slow and limited. Also noted that more than 5 calls of a DR program (presumably CBP) resulted in dramatic decreases in participation by DR customers.

Funding vendors instead of customers might be OK for HVAC or chiller plants, but lighting is probably too small a load to consider. Difficulty is putting a dollar value on DR if it can't provide a reliable long event response. Noted that frequency response is more lucrative. Commented that in PJM (these are the numbers he gave) traditional DR is awarded at \$35k/MW vs. \$180K/MW for frequency response.

DRAM was OK for this company in 2016 as there were no actual calls for load reductions but customers tested their portfolios to qualify for RA, so they were paid as standby capacity. However, when this aggregator didn't get a contract for the next year, they had to go to customers and say "we are back to the multiple calls for DR" and customers dropped out. A hindrance is that customers can see a lot of reserves on the calling entity's website, so they wonder why DR events are being called.

Company C – Manufacturer of control devices

This company supported OpenADR 1.0 for many years. Later, they developed a certified client to support of OpenADR 2.0a and b via a gateway box. In the last year, they only sold 3 licenses across US, all in California. At an early 2017 national meeting, there was discussion about Automated DR. They expected to see more business but found that incentives were not attractive enough and the programs are too complicated. They noted that they have had global set point adjustment in their product for over 20 years, and this is now a code requirement. This company is very supportive of the idea of developing upstream incentives for distributors as the dealers could offer something in their toolkit that would generate interest and awareness. As with company A, the sense was that a company that knows the DR programs would be best able to help customers participate more effectively.

In early 2017, they had an agreement with PG&E to put OpenADR in 100 big box retail stores. They are adding software, configuring the VEN. The effort is run out of their national accounts group, and uses Openadr 2.0a.

Company D – installed equipment using ADR rebates

They obtained an advanced HVAC+R ADR rebate (\$350/kW of reduction instead of a standard \$200/kW) from PG&E recently for a VRV ADR control which hasn't been commercialized. This VRF test system had more than 50 zones. After the successful test at a senior center in Livermore, the system was taken out and it is NOT on the market yet. They considered the test successful.

Company E – Residential equipment using OpenADR

The purpose of this interview was to explore pricing schemes for OpenADR for home automation. This interview also reviewed some of the challenges in OpenADR for residential automation.

This company asked if they could host a native dedicated OpenADR chip. Their new chip was powerful enough for the SSL. But it costs more to have a

Wi-Fi chip that does SSL, hence the number of IoT products that are hacked. Then there is the issue of the SSL yearly certificate. In small volumes they are quite expensive: this makes a \$40 certificate (yearly fee) on a \$100 Tstat cost prohibitive. However, in large volumes (tens of thousands), maybe the yearly charge to SSL certifier would be manageable, nevertheless, in small pilot volumes, they remain expensive. In the short run, it is cheaper and easier to use a cloud OpenADR communication.

The company has been in discussions regarding water heater distribution channels. For example, the purchase of an OADR 'module' in a water heater could be done at any large retail chain, but because OpenADR implementation is regional so the user would need to know the IP address for the local utility OADR VTN, and this adds to the complexity of installing OpenADR.

To make implementation simpler, this company has been focused on using CTA 2045 which is a modular communication interface for end-use devices. In general, the standard can support Cellular, WIFI, broadband, paging, or other communication system. This company currently has AC and DC Wi-Fi modules, AND a cellular OADR module (that translates OADR to CTA-2045), but that module is a lot more expensive than the Wi-Fi with no OADR.

With ORNL and Southern Company, this company is also developing a Volttron home automation gateway with every device under management intended to provide transactive energy and control. The company will be shipping this product to the commercial building market in 8 weeks, with Volttron on it, but the actual Volttron agents that ORNL is developing may not be ready at that time.

Today most OpenADR systems in homes are ONLY cloud based OADR.

This company has been involved with utility pilots for almost a year with their CTA-2045 modules and easy to use DRMS for a variety of utilities across the USA. These pilots have included web and mobile apps for the end use customer, and the DRMS for utilities, working on a variety of end-use products such as thermostats and retrofit water heater switches, pool pumps and EV charging systems.

Their pricing is expected to be based on volume and duration of service. They also know some utilities want a private cloud, which will cost more. They think that costs for residential automation are something like:

- 1st cost hardware (varies for different cloud thermostats and other devices)
- one time set up costs (may only be \$5)
- \$5 per device per year API fees if a middleware DRMS is used such as Energy Hub, or Auto-Grid. They have heard some vendors say they charge between \$4-7 per device per year.

- \$5-10 per device per year if this company's DRMS, continuous monitoring, and predictive platoon analytics are used.

Company F – Large controls supplier

This company had partnered with an aggregator to offer OpenADR. It was never directly included in their specific product, but could be included if required for Title 24 compliance. They have worked with OpenADR gateways. We explored whether this company would consider providing OpenADR and reporting on Open ADR as part of a monthly service contract. Company indicated that only 8-9% of customers have service contracts.

We spoke about what services the company could provide –

- Configure the automation, develop sequence of operations
- Maintain communications
- Verify controls and energy performance

It might make sense to add the DR automation to go with a tune up service. Most customers wait for many years and then may want to upgrade their software.

If we were to combine retro-commissioning and DR we might consider

- Revisit and review sequence of operations
- Address deficiencies
- Test and develop DR sequences

Perhaps a pilot test could explore providing a 2-year contract for these new services to determine and build the local capability.

Company G – utility outside of CPUC that implemented energy efficiency with upstream and midstream incentives

Upstream = paying manufacturer to promote or provide energy efficiency within region; primarily lighting (over \$1M at utility to mfgs, they provide to large retailer at low price that passed the low cost on to consumers). Responsibility of utility project managers to do displays at retail stores. Manufacturer printed "brought to you by UTILITY" on package for buy down packages.

Washing machines, TVs, refrigerators, dishwashers, etc. went to big box (SEARS mostly). Would only purchase next tier (energy star 5 for example), then incent next level (ES6). \$X/unit for the sale to the retailer and an incentive to customer as well. Pay to phase out (incentive moved to other model) after target met, then incent to go to next level. No rebate once reached target level.

Utility would also supply collateral marketing for qualified units. As things moved in and out of programs, had to work to change labelling as well in coordination. Retail not responsible for taking marking off old ones or marking new ones. Noted that the effort was very time and labor intensive to implement.

Wanted to automate more of this (e.g. websites); maybe focus on online shopping or see online that there was a rebate, but retailers didn't like this at all. Part of it was need for regional focus to exclude regions covered by other utilities. This particular effort did not include any DR upstream or midstream effort.

Tried to get pool pump project going – with 20%+ pools in area via the National Swimming Pool Association. Held workshop to get manufacturers to push upstream for VFD pumps with AutoDR or other but did not gain momentum. Manufacturers interested but insufficient funding – needed 3-5 year champion for continuity. Interested in direct load control (DLC) or AutoDR in pool pumps but no follow through. Retailers also said, very loudly, that VFD not needed, no reason to spend extra when single speed sufficient. So retailers were not receptive to carrying these, as they were not perceived in best interest of customer.

There were not many manufacturers willing to put DLC in single speed pumps but this adds cost. But these are low margin and sell well at the current price. Including DR component would change market price as well as a manufacturer process, without clear benefit to retailer. VFD pumps already in market, slowly increasing in market, more receptive to ADR because already within profit margin. VFD pumps run longer and are more efficient but the market is more used to existing turnover of single speed pumps. It might have helped to have customer education to show only need to run pump for limited time, not all the time. But no traction here, despite huge potential for DR. Retailers will sell what they can sell. Won't promote more efficient drive pool pumps unless they were incented to do so.

Retailers that this utility was talking with had in mind that they were OK with incentive to help sell the product. Payment to educate customer is a burden either for manufacturer or utility. Has to be specific to particular utility. Requires installer to take classes, utility to create and hold the classes. Noted that it is easy to underestimate the time required for this.

Holistic home improvements require detailed websites, rebate programs that include audit that utility had to review. Installers had to sit through several days of training to get certified, do audit, put into system, calculate amount of rebate could get. Could \$5,000-12,000 per home or with more equipment or larger size home could be upwards of \$20K (combine gas and electric rebates and clever use of rebate choices) – this might mean cost to

consumer was ~\$60K. Utilities were under pressure to spend it all NOW (within 2 years) or lose it all. Very labor intensive for installers and project managers at utilities, as well as customers who had to be there for process. Engagement with customer meant they also had to be there.

Company H – thermostat developer

This company went through the process of integrating OpenADR about 6 years ago. They found it very difficult to integrate with the Akuacom VTN; it took 9 months to a year and cost them \$100k. The person we spoke with said he still gets grief from his CEO about that investment, because they have never sold an OpenADR thermostat since getting certified (and it's not even listed on their website, but they may work directly with utilities to tailor their offering). We asked how difficult it is for a homeowner (when doing a thermostat self-install, which is something like 70% of their sales) to subscribe their OpenADR thermostat with the utility's VTN. Our contact reported that it is all done transparently behind the scenes and the homeowner never knows about it. Our contact noted that the issue of certificate cost for individual thermostats is a real problem for them also.

Since this product's APIs have been public for several years, they have over 4000 developers using the APIs, and this could be making a standard like OpenADR unnecessary.

DR programs:

Most of their participation in DR programs is through the platform providers like alarm.com and Energy Hub. They have ~200,000 units installed in small commercial buildings and have a special energy management product for small commercial buildings.

Upstream Incentives:

This company can process upstream incentives for energy efficiency programs and it sounds like this is a routine thing (upstream in this case means the customer never sees the rebate, it's subtracted from the price they pay before they ever see the price. Because these are applied at the time of purchase, they are probably more accurately midstream programs). There are several different mechanisms for processing the incentives.

- Via an online store: if the customer purchases the thermostat from the company's site, the utility can first give the customer a promo code for the utility rebate, which the customer enters at checkout and they pay only the discounted price. The promo code is unique, so only the program participants can get it, and the promo code links a particular customer to a specific thermostat. The company can track which thermostats are connected to the its cloud, so when the customer receives the thermostat, they get a reminder to install it if it hasn't connected to the cloud within 7 days. If they don't

connect the thermostat within the 30 days, the rebate is rescinded for that customer and the utility collects it as a charge on their bill.

- Via third parties: Many utilities are now contracting with 3rd parties to run "marketplaces" for their customers to buy energy efficient and connected products. The advantage of these market places is that the rebates are already applied to the prices that the customer sees, which makes rebate processing much easier. It looks like the marketplaces don't actually sell the products, but provide referrals to other online stores (e.g., Best Buy, Amazon, Home Depot) that actually sell the products.
- Retail: In a physical retail store, it's still possible to apply the incentive before the customer buys the product, using this process: 1) there is a sign on the shelf next to the thermostats saying that rebates are available, with a link or QR code to follow to sign up for the rebate, 2) the customer scans that link on their phone, goes to the utility web page, enters some info that identifies them as a unique customer (name and last four of SSN, or phone number, or some other info the utility has about them), and gets a bar code on their phone for the rebate, 3) the customer takes the thermostat to check out, the cashier scans the thermostat bar code and the rebate bar code on the phone, and some magic happens on the retailer's and utility's backend computer systems to apply that rebate to that thermostat, 4) customer pays the normal price less the rebate.

This company has never done an upstream incentive for thermostats for DR programs. Usually, the residential DR programs are "bring your own thermostat," so the program is simply enrolling thermostats that the customers have already purchased without a rebate. But he said it would be possible to enroll the customer in the DR program or TOU tariff before they buy the thermostat and get the rebate. This would be done by requiring DR program signup in order to get the promo code (in the case of online purchase) or the customer would have to sign up for the DR program on the phone in the retail store, in order to get the bar code for the rebate to take to check out. He wasn't sure how viable the in-store option would really be, since you're potentially asking someone to change their utility rate while standing in a large retail store looking at their phone. But it's technically possible to do this.

This company thinks that the "sweet spot" for incentive level is about \$100/thermostat, given that it's a product that costs \$175 to \$250 at retail. If it's \$50, people don't pay attention, but \$150 gets too many people to buy them who wind up not using them.

Company I – Thermostat aggregator

This company runs a lot of programs (21-25 utility programs) that aggregate connected tstats for DR or EE with HVAC. These are mostly residential, but there are some commercial also. 7-8 major service providers that put thermostats in homes. All use different technologies: wifi, gateway in home, etc. This company aggregates all these into a common platform for the utility and handles all the things behind the scenes: enrollment, checking the customer is on a compatible rate, customer approval process. Once approved, EH has telemetry in place between vendor and utility. Utility runs events through EH portal.

Key steps:

- Marketing
- Enrollment
- Dispatch
- M&V

They are a certified OpenADR 2.0a VEN, can do some of the 2.0b functions, but it hasn't been worth getting certified. OpenADR only covers two of the key business processes: dispatch and M&V. Need other systems to cover marketing and enrollment. So, it hasn't been worth their investing in the 2.0b certification.

They do use OpenADR with some utility customers but it sounds like very few. Some customers have done the OpenADR integration but decided not to use OpenADR for the actual event dispatch. Feel that's because their DRMS is very robust and has a good interface. OpenADR gives coordinated response across multiple programs, using the VTN. Can communicate to several aggregators through one DRAS. The OpenADR interface is useful when a utility wants to call a coordinated event using resources from several aggregators, so the utility just enters the event once in their DRAS and it gets distributed to several aggregator VENs.

- Is this company involved in the sale of the hardware?

Yes, there are programs where the utility gives away the thermostat. Or a utility may have an EE program that incentivizes thermostats for new installs. SCE has a BYOT program that pays \$125/thermostat. Vendors actually sell products for less than the incentive and customer gets the difference, e.g., another company with their WiFi thermostat that costs about \$110. A lot of the utility online marketplaces have upstream rebates for light bulbs and thermostats. Connected thermostats have a verification step.

- OpenADR costs: is the certification the main cost?

The cost stream of OpenADR: building software and certifying is a one-time cost, so not too burdensome. Key cost is the cost of the connection

(integration) with a specific utility. Integration cost with the VTN can be expensive: in one case with a California utility, it cost as much to do the integration as they earned on the program. (it sounded like this was their first OpenADR program, so costs were high) EH feels like there's a transaction cost to integration that means they can't do it for zero cost. More recent integration has gone smoother. Non-trivial transaction cost to do the integration. This was driven by the OpenADR 2.0 certificate authority (CA); OpenADR has its own CA, it's non-standard. Standard software libraries import standard CAs (like Verisign) and it's easy; that's not true with OpenADR. At that time, the OpenADR CA was set up assuming they would be providing certificates for lots of individual devices. When this company asked for 2 certificates for the cloud service, the CA sounded like it didn't fit their business model. Certificates cost about \$2 each.

*[Need to find out if OpenADR still has its own CA]

- Would they do OpenADR 2.0b?

Yes, if a customer asked for it. There would be some non-recurring engineering costs they would need to figure out how to recover, e.g. all from that customer or pro-rated across their customer base.

- What's the DR program cost stream?

Vast majority of thermostat incentive programs are for DR, not EE. The flow of incentive dollars is such that first, an incentive goes to the customer to get their enrollment, then some dollars go to the OEM and the aggregator (shared), and then an ongoing incentive to the customer for participation.

APPENDIX B: RELEVANT RESEARCH

A key distinction between EE and DR is that EE is any time, so simply installing the equipment is sufficient. With DR, there is a need to show ability and willingness to alter load when called. Whether some form of test of those is needed beyond equipment installation is TBD.

The report on HVAC notes that most customers purchasing HVAC are concerned with:

- Delivery time
- First cost of equipment
- Cooling needs
- Footprint of new equipment
- Structural issues.

The DR incentive could cover most of this with incentives for (qualified) preferred provider or preferred equipment.

Cost data collected during the study to develop the incremental measure cost were:

- ADR costs
 - unit controller
 - DRAS client
 - installation labor
 - configuration and connection
- Other costs
 - recurring services and fees (I could see how these might go into the category above, this is where they put them)
 - support hardware

Incentives were offered to contractors and distributors (they interviewed 3 controls contractors, 3 controls manufacturers, 4 DRAS manufacturers, 2 HVAC contractors, 4 HVAC distributors, and 1 HVAC manufacturer).

Incentives were as follows:

Thermostats - contractors only, DR enrollment required in all cases:

- \$150/thermostat if cloud connected
- \$250/thermostat if onsite connected

Unitary AC - incentive offered to contractors and distributors

- \$40/ton if DR enabled

- \$80/ton if DR enabled and enrolled in DR program

VRF - offered to distributors only

- \$2,000 per project if DR enabled
- \$4,000 per project if DR enabled and enrolled in DR program

Tempering enthusiasm:

After targeting market actors with DR experience, nine opportunities were generated in the study year (2015), three contractors and two HVAC distributors signed participation agreements as a result of this study, with one more HVAC distributor showing significant interest at the conclusion of the study. At the conclusion of the project (only) three ADR-enabled projects were installed - apparently all in the same school district. The distributors were large, however: combined they reportedly represented over 50% of distributor sales. Even with this strong support, the study entailed an extensive semi-monthly contact with staff at the targeted market actors to enhance their knowledge of DR and how it could be extended to other loads, such as lighting.

In one case, the contractor did not even broach the subject of ADR until HVAC equipment had shipped to the site. Another contractor focused solely on upgrading controls on a high-efficiency HVAC until that was installed months before.

APPENDIX C: ANALYTICAL MODELS

ENERGYPLUS MODEL

For small and medium commercial buildings, the EnergyPlus model includes thermal zones, HVAC, and plant models. Small and medium commercial office buildings are equipped with packaged direct expansion (DX) variable air volume (VAV) cooling systems. The availability of DR potential from building HVAC systems is determined by HVAC operational schedules, which varies along with building types. Typically, it operates from 6AM to 6PM in small and medium commercial buildings.

Figure C-1 shows examples of HVAC response to global temperature adjustment (GTA) in a medium commercial building. Notice that the building HVAC system load can be reduced by increasing thermostat temperature setpoint. We repeated this simulation of GTA control strategy during the DR event hours (e.g., 2PM to 6PM) for each weekday in the summer. At the end, all the results are summarized to fully capture the HVAC power responses to the GTA control strategy in a typical summer season.

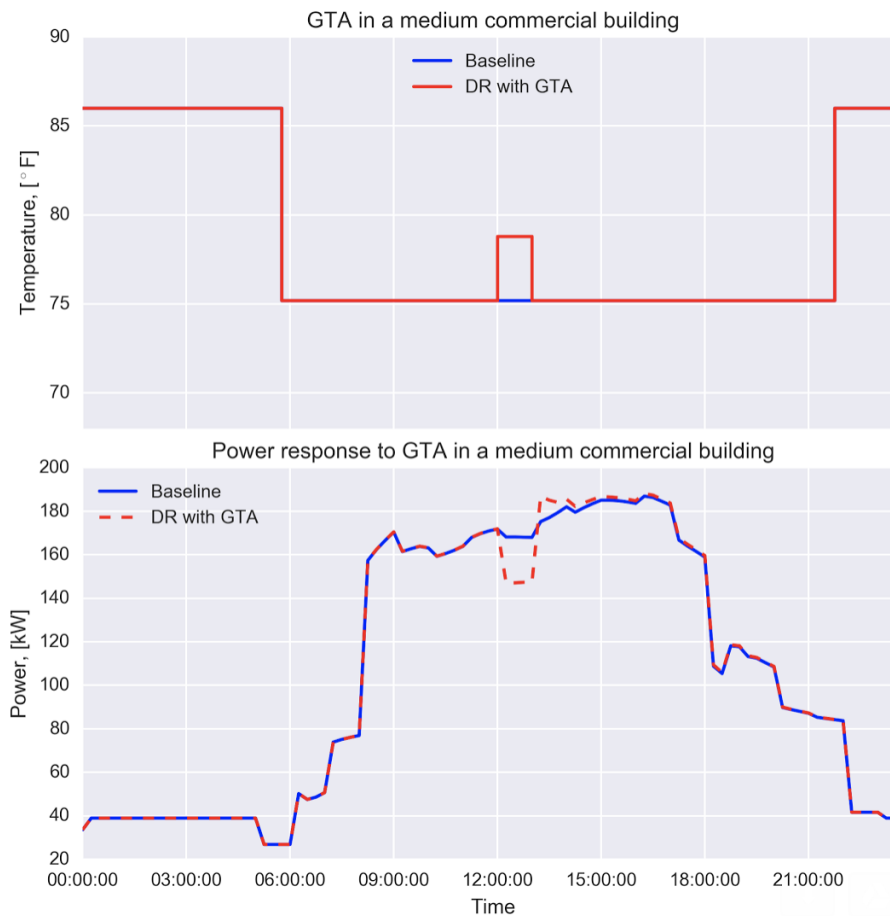


FIGURE C- 1. TEMPERATURE AND POWER IMPLICATIONS OF GTA IN MEDIUM COMMERCIAL BUILDING AS MODELED BY ENERGYPLUS

FASTTRACK MODEL

For small to medium office and retail business (SMB) customers (less than 500 kW of peak demand), the PG&E ADR Program offers a “FastTrack” program to streamline the application process on the following eligible DR technologies:

- Space Cooling
 - Increase thermostat temperature
 - Cycle off compressors
 - Cycle off fans along with compressors
- Dim lighting

Or,

- Global Temperature Adjustment (GTA) for Packaged Units AC
- Cycle on/off Packaged Units AC
- Lighting DR strategies (Dimming or Switching on/off)

The projects get paid 100 percent of eligible incentives upon successful inspection and verification of a load shed test. In addition, FastTrack customers agree to enroll in an eligible PG&E Demand Response (DR) Program and to participate in DR events for 3 years.

LBNL MODEL VS. FASTTRACK MODEL

Earlier, Figure 9 compared the predicted kW shed estimation from LBNL EnergyPlus based model with the load reduction deemed by the PG&E FastTrack Model at the Stockton site. The figures below show similar comparisons for two additional sites in California.

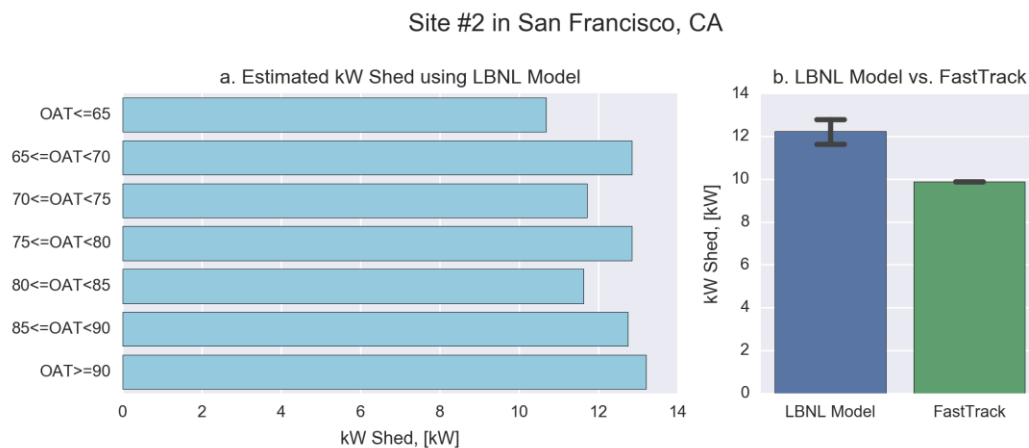


FIGURE C- 2. PREDICTED kW SHED VS FASTTRACK MODEL (SAN FRANCISCO, CA)

Site #3 in San Rafael, CA

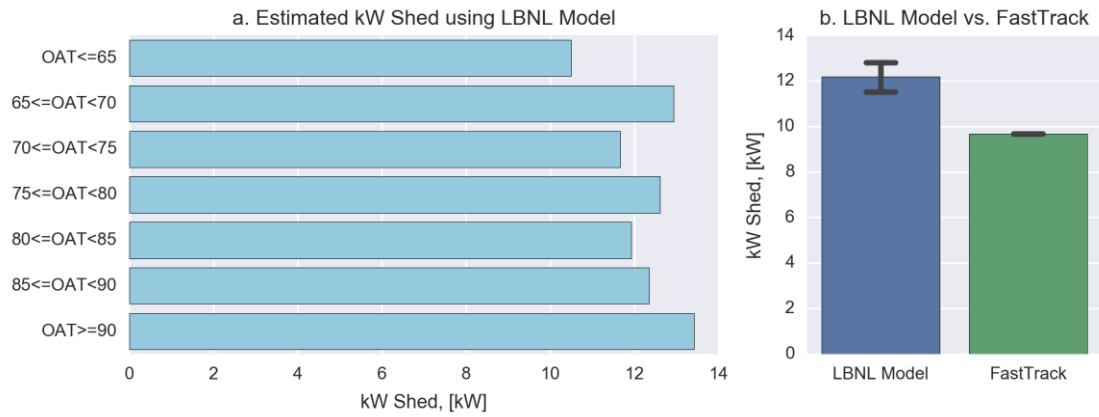


FIGURE C- 3. PREDICTED kW SHE VS FASTTRACK MODEL (SAN RAFAEL, CA)