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An Analysis of Structural and Psychological Barriers to the Adoption of Demand Response Smart Grid Technologies: Lessons Learned

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Executive Summary

Utilities are increasingly implementing smart grid programs that provide customers with consumer-focused demand response technologies which aim to reduce peak demand. This report examined the success these technologies have had in reducing peak demand for smart grid programs. By examining findings from smart grid programs across the country and the Department of Energy's Final Report on Customer Acceptance, Retention, and Response to Time Based Rates from the Consumer Behavior Studies, the following findings were identified for the success of consumer-focused demand response technologies in reducing peak demand.

1) **Web Portals** – The widespread adoption of web portals in smart grid pilot programs indicates that they likely are effective but a lack of data to evaluate them does not make this certain.
2) **In-Home Devices** *(IHDs)* - The effectiveness of IHDs on reducing peak demand is inconclusive and the offer of IHDs to customers negatively impacts benefit-cost ratios.
3) **Programmable Communicating Thermostats** - PCTs significantly reduce peak demand and positively impact benefit-cost ratios.

This report also examined data from residential customers in National Grid's Smart Energy Solutions (SES) program from 2015 and 2016. Analysis of this data found that SES customers who adopted at least one of the consumer-focused demand response technologies had high rates of average peak demand reductions of 16.8% in both 2015 and 2016. In contrast, customers who did not adopt any technologies had average peak demand reductions of 1% in 2015 and 4% in 2016. Based on these findings, it is clear that there is a correlation between the adoption of these demand response technologies and achieving higher rates of peak demand reduction. However, only 24% of National Grid's SES customers had adopted at least one of these technologies by 2016. Therefore, how can National Grid and other utilities increase adoption rates? This report addressed this question by identifying and analyzing structural and psychological barriers faced by customers to the adoption of demand response technologies.

Structural Barriers – Alternative Energy Supplier, Internet Access, Central Air Conditioning
Psychological Barriers – Awareness & Knowledge, Liking & Preference, Conviction & Purchase, Loyalty

Based on findings, the following recommendations were provided to National Grid for how to overcome these barriers, increase technology adoption rates and reduce peak demand.

Recommendations

1) Determine Benefits and Costs of Technologies
2) Analyze Energy Use of Customers who Discontinue Use of Technology
3) Include the Environment and Society in Future Marketing
4) Increase Focus on Web Portal and Smart Phone App
5) Increase Focus on PCTs, Target Customers with Central Air Conditioning
6) Revaluate Survey Questions to incorporate the Technology Acceptance Model (TAM)

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Terminology Utilized

Below is a list of the key terminologies used throughout this report along with explanations.

CDR* (Conservation Day Rebate) – The second rate structure available to National Grid SES customers which they could opt into from the SRP rate structure.

CPP* (Critical Peak Pricing) – One of the rate structures utilized by smart grid programs.

CPR* / PTR* – Critical Peak Rebate or Peak Time Rebate. Both acronyms stand for the same type of rebate based rate structure. However, the DOE used the CPR acronym and Navigant and National Grid used PTR.

DOE – Department of Energy.

IHD (In-Home Device) – A physical device placed in a home or business which provides utility customer with near real time information about their electricity consumption and costs.

LCD (Load Control Device) – An electric outlet which enables utilities and/or customers to automatically change their appliances' energy consumption based on price signals sent by a utility.

Navigant Consulting Inc. – Third party consultants hired by National Grid for analysis of their SES program.

PCT (Programmable Communicating Thermostat) – A thermostat which enables utilities and/or customers with central air conditioning to automatically change their energy consumption based on price signals sent by a utility.

Peak Demand/Peak Load –When the amount of electricity demanded by utility customers is expected to be maintained at a significantly higher rate for a sustained period of time, often causing greater stress to the grid and leading to a greater chance of a power outage.

SES (Smart Energy Solutions) – National Grid's smart grid pilot program in Worcester, MA

SRP* – Smart Rewards Pricing. The rate structure that SES customers were automatically enrolled into.

Smart Grid - Technology which is being used to bring utility electricity delivery systems into the 21st century, using computer based-remote control, automation, and increased information sharing with customers.

SMUD – Sacramento Municipal Utility District.

TOU* – Time of Use rate. A type of rate structure which charges utility customers different rates per kwh at different times.

Web Portal – An online website which provides utility customers with near real time information about their electricity consumption and costs and insights for how customers can save electricity and money.

* These pricing plans are explained in further detail in the National Grid SES Program section on pages 10 – 11.

Background

Context for National Grid Capstone Project

During the past decade, America's utility grid has undergone fundamental changes on a scale not seen during the past 100 years (Energetics Incorporated, 2014). These changes have largely been driven by the need to replace aging infrastructure, modernize the grid, incorporate new sources of energy, and better balance the supply and demand of energy. In order to address some of these changes, utilities have increasingly implemented smart grid programs that provide customers with consumer-focused demand response technologies that aim to reduce peak demand. This report examined the success these technologies have in reducing peak demand for smart grid programs by utilizing National Grid's Smart Energy Solutions (SES) program as a case study and drawing on learnings from other smart grid programs. In the summer of 2016 John Richards met with Nicholas Corsetti, Senior Program Manager at National Grid, to discuss the needs of National Grid for this project. During these discussions the following goals of the project were agreed upon:

1. Benchmark National Grid's SES demand response technologies against other smart grid programs.
2. Provide National Grid with recommendations on how to improve the adoption rate of demand response technologies for current and future programs.

By benchmarking National Grid against other smart grid programs, and identifying structural and psychological barriers to the adoption of demand response technologies, recommendations have been provided to National Grid for how to increase the adoption rates of demand response technologies. Increasing adoption rates will in turn lead to a reduction in peak demand and less stress placed on the grid and lower energy costs for utilities and consumers.

Changes to the Grid

The introduction of variable renewable energy sources like wind and solar has introduced greater variability to the flow of electricity throughout the grid. Given that electricity generation doubled for wind from 2010 to 2015 and tripled for solar from 2013 to 2015, the stresses placed on the grid from these variable power sources will continue to grow (U.S. Energy Information Administration, 2016). The stresses placed on the grid have exacerbated problems associated with the grid's aging infrastructure and it is estimated that by 2050 nearly every single power plant in America will need to be replaced. (Bakke, 2016).

In response to some of these challenges, the American Recovery and Reinvestment Act of 2009 provided the Department of Energy with $4.5 billion to modernize the electric power grid (U.S. Department of Energy , ND). Through this program the DOE and the utility industry jointly invested $8 billion in 99 cost-shared projects involving more than 200 participating electric utilities and other organizations to modernize the electric grid (U.S. Department of Energy , ND). This investment has served as a catalyst for utilities across the nation to upgrade their grid infrastructure and develop a smart grid.

Smart Grid Demand Response Technologies

One area of focus for many of these smart grid programs is on demand response. Demand response refers to "changes in electric usage by demand-side resources [customers] from their normal consumption patterns in response to changes in the price of electricity over time." (Federal Energy Regulatory Commission, ND). Historically, during times of high demand for electricity, utilities have to turn on dirty, inefficient, and costly power plants to supply power. These extra costs are rolled into a fixed, flat rate that all customers pay. With a fixed rate, utility customers have no incentive to reduce power during times of high demand. Utilities have sought to better balance the supply and demand of power by introducing "time based rates" where customers are charged more during times of high demand and less during times of low demand (SmartGrid.gov, ND). These "Time based rates" create a financial incentive for customers to reduce their energy usage during times of peak demand.

One of the tools that demand response programs rely on is consumer-focused technology. These technologies have been utilized by utilities in demand response programs across the country (U.S. Department of Energy, 2016). Some of the types of technologies include: Web Portals, IHDs (In-Home Devices), PCTs (Programmable Communicating Thermostats) and LCDs (Load Control Devices) which help provide ways to raise customer awareness regarding their usage levels, consumption patterns, electricity prices, and costs [Figures 1, 2, 3,4] (U.S. Department of Energy, 2016). In addition to increasing customer awareness of their energy usage, technologies like PCTs and LCDs allow for automated control of energy by customers and utilities. For example, if the price of energy is raised during a hot summer day, PCTs and LCDs can automatically respond to reduce a customer's energy usage. However, the adoption rate of these technologies by customers has varied substantially across different programs and technologies.

Source: National Grid

Figure 1 - Web Portal (Navigant, 2015)

Source: National Grid

Figure 2 - Picture Frame (IHD) (Navigant, 2015)

Source: National Grid

Figure 3 - Programmable Communicating Thermostat (PCT) (Navigant, 2015)

Source: National Grid

Figure 4 - Load Control Device (LCD) (Navigant, 2015

National Grid SES Program

In 2012 the state of Massachusetts passed the Green Communities Act that mandated that all investor owned utilities implement a smart grid pilot program. In response to this National Grid received approval from the Massachusetts Department of Public Utilities for a two year pilot program in Worcester, Massachusetts called Smart Energy Solutions (SES). Twenty five percent of Worcester residents were selected to participate in SES and from 2012 – 2013 nearly 15,000 “smart meters” were installed adjacent to customer buildings. These “smart meters” monitored energy usage in near real time and communicated with National Grid and demand response technologies. In January 2015, nearly 11,000 of the 15,000 utility customers with smart meters were enrolled in the two year pilot program which lasted through December 2016, and has recently been extended[1] . The heart of the program focused on giving customers greater control, choice, and convenience over their energy usage (National Grid, 2016).

[1] The remaining customers could not be enrolled into the program because they were enrolled with an energy supplier other than National Grid.

Customers were automatically enrolled into the SES pilot program and given a choice to leave the program; this is known as an "Opt-Out" program and contrasts with an Opt-In program where customers are solicited to participate. Customers enrolled in the National Grid SES program were automatically placed on the smart rewards pricing rate plan (SRP). The SRP is a combination of a time of use (TOU) and critical peak price (CPP) rate (SmartGrid.gov, ND). Figure 5 shows the SRP rate structure. With the SRP rate structure, customers pay a lower rate every day of the year when compared to their current basic, fixed rate. The blue bars in Figure 5 represent the "on peak" rate that is Monday – Friday from 8:00 am – 8:00 pm when customers pay a slightly lower rate than their basic fixed rate. The green bars in Figure 5 represent the "off peak" rate that is Monday - Friday from 8:00 pm – 8:00 am and weekends, when customers pay an even lower rate.

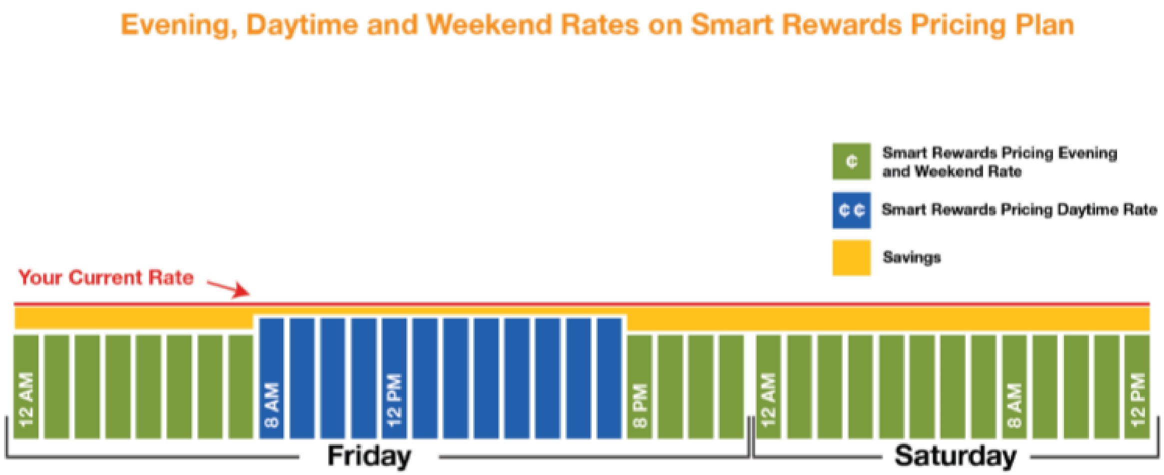


Figure 5 - Smart Rewards Pricing Plan (Navigant, 2015)

In addition to the SRP rate in effect every day, National Grid can call "conservation days" up to 30 days a year when a higher rate is charged during certain "peak event" hours. The red bars in Figure 6 show the rate charged during a "peak event" where customers can pay up to five times more than the "off peak" rate.

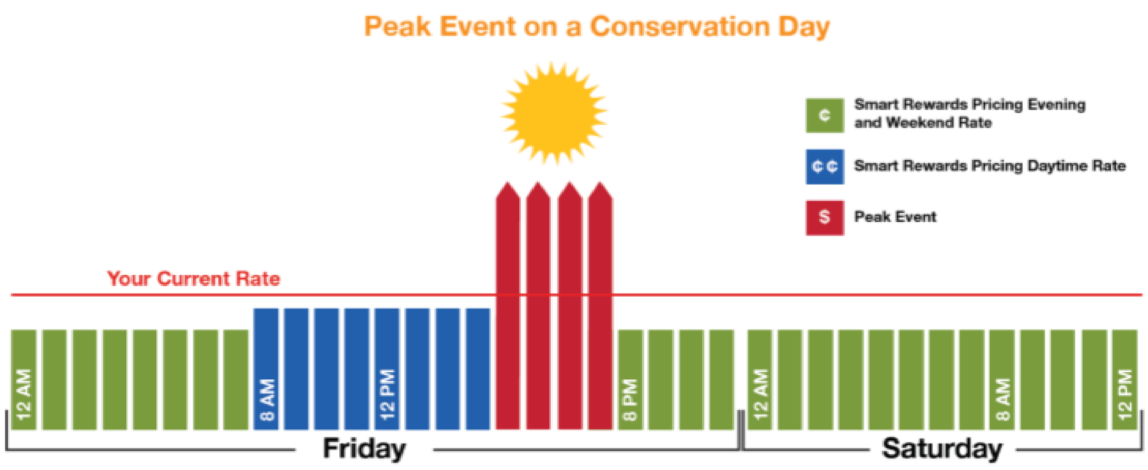


Figure 6 - Smart Rewards Pricing Plan - Peak Event (Navigant, 2015)

If customers enrolled in the National Grid SES program did not prefer the SRP rate, then they had the option to opt-out of the entire SES program altogether or stay in the SES program and enroll into another rate called the conservation day plan (CDR). The conservation day plan is a form of peak time rebate (PTR) (SmartGrid.gov, ND). The CDR allows National Grid SES customers to stay on their basic, fixed rate but still earn a rebate when they reduce electricity consumption below their normal energy use during a peak event (Navigant, 2015). Among the 10,849 SES customers approximately 96% were enrolled in the SRP and 4% were enrolled in the CDR (Navigant, 2015).

Important Information about Pricing Plans:

Because the vast majority of National Grid's SES customers (96%) were enrolled in the SRP, this report focused on analyzing the results from SES customers enrolled in this rate structure. Within Navigant's reports, and in the tables and figures in this report, National Grid's SRP rate is referred to as CPP, and National Grid's CDR rate is referred to as PTR. This is so that consistency in terminology can be maintained when comparing National Grid's rate structures to other smart pilot programs rate structures.

National Grid SES Demand Response Technologies

Time based rates give customers a financial incentive to conserve energy during times of high demand or switch their energy usage to times when energy demand is lower. Consumer-focused demand response technologies like web portals, IHDs, and PCTs can be thought of as the tools that enable customers to take action to reduce and shift their energy use to times of lower demand. National Grid's SES pilot program offered customers several different types of consumer-focused demand response technologies at no cost, with free in-home installation, and in person instructions for how to use the technologies provided. Below is a description of the technologies available to customers.

Foundational Infrastructuere (Provided to all customers) – This includes a smart meter and access to a web portal with electricity usage information available through a desktop computer or mobile device. This includes technology Level 1, which is detailed in Table 1 below. (Navigant, 2015).

In-Home Devices (Required customer solicitation) – This includes any of three additional devices: a communicating digital picture frame (IHD), a Wi-Fi-enabled smart thermostat (PCT), and smart plugs and load control devices (LCD). This includes technology Levels 2 – 4, which are detailed in Table 1 below (Navigant, 2015).

National Grid's SES program divided these technology offerings into four separate levels; as the level increased, so did the technology offerings. National Grid customers start out with the Level 1 basic package where an online web portal displays their energy usage and cost in near real time by connecting to their smart meter. Each level increase adds another type of technology. It is important to note that the adoption of each of these technology offerings has a corresponding technology requirement. For the web portal and IHD, all customers must have access to and utilize an internet connection. For the PCT, it is prefered that customers have access to and utilize an internet connection, wifi, and central air conditioning. However, in 20 – 30 cases where customers do not have an internet connection, National Grid has installed a "gateway" device which communicates directly between the PCT and the smart meter, eliminating the need for wifi. However, because of the extra cost of this device, utilizing internet and wifi is preferred.

National Grid SES Consumer-Focused Demand Response Technologies		
Technology Level	Technologies	Technology Requirements
1	Web portal (Web portal is accessible through desktop or mobile device via internet or mobile app)	Internet connection
2	Web portal, mobile app, and communicating digital picture frame (IHD)	Internet connection
3	Web portal, mobile app, and communicating programmable thermostat (PCT)	Internet connection, wifi, central air conditioning
4	Web portal, mobile app, communicating digital picture frame (IHD) communicating programmable thermostat (PCT), and load control devices (LCD)	Internet connection, wifi, central air conditioning

Table 1 - National Grid SES Consumer-Focused Demand Response Technologies (National Grid Interim Report, 2015, p 36)

National Grid SES Customers Enrolled in Technology Levels

The data in Table 2 below comes from Navigant's 2016 SES demand response impacts report. Results are broken down for 2015 and 2016 by technology level, pricing plan (CPP or PTR), and active or passive. All SES customers were automatically enrolled in Level 1 and were considered "passive" until they logged into their web portal account making them an "active" customer. All SES customers in levels 2 – 4 were active because they took action to acquire one of the SES program's in home technologies. In the bottom of Table 2 we can see that in 2015, approximately 19.9% of SES customers were active and utilized at least one of the technologies. By the end of 2016, approximately 24.3% of of SES customers utilized at least one of the levels of technologies. This was primarily the result of an increase in the number of SES customers accessing the web portal.

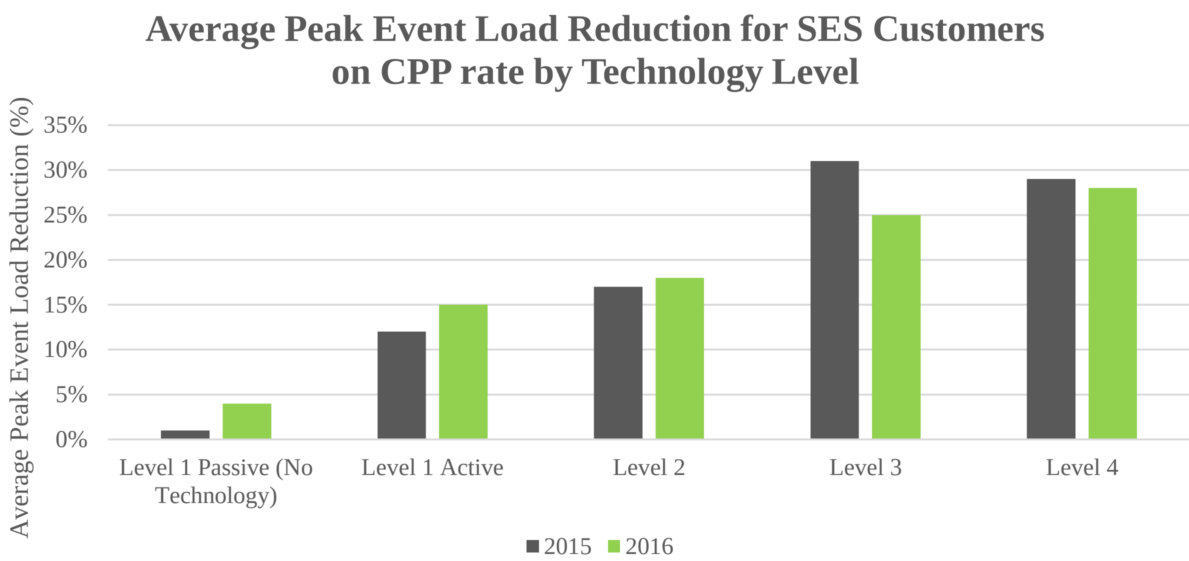
National Grid Consumer-Focused Demand Response Technology Adoption Totals						
	Aggregate Numbers			Percent of Total		
Customer Level	2015	2016	Change	2015	2016	Change
Level 1 CPP Passive	8,358	7,894	-464	76.8%	72.9%	-3.9%
Level 1 PTR Passive	363	296	-67	3.3%	2.7%	-0.6%
Level 1 CPP Active	1,208	1,602	394	11.1%	14.8%	3.7%
Level 1 PTR Active	73	77	4	0.7%	0.7%	0.0%
Level 2 CPP Active	568	646	78	5.2%	6.0%	0.7%
Level 2 PTR Active	31	25	-6	0.3%	0.2%	-0.1%
Level 3 CPP Active	27	28	1	0.2%	0.3%	0.0%
Level 4 CPP Active	237	242	5	2.2%	2.2%	0.1%
Level 4 PTR Active	16	13	-3	0.1%	0.1%	0.0%
TOTAL	10,881	10,823	-58			0.0%
TOTAL All Levels (Active)	2,160	2,633	473	**19.9%**	**24.3%**	4.5%
TOTAL Levels 2 - 4 (Active)	879	954	75	**8.1%**	**8.8%**	0.7%

Table 2 - National Grid Consumer-Focused Demand Response Technology Adoption Totals (Navigant, 2016)

National Grid SES Pilot Results

The results for the first year of the pilot point to fairly broad success. Overall the program achieved a 98% retention rate and a 72% customer satisfaction rate (Navigant, 2015). Massachusetts' Green Communities Act for 2008 mandated that smart grid pilot programs have an overall objective of reducing active participant's peak demand and overall energy demand by 5% (Navigant, 2015). National Grid's SES program adopted and exceeded these goals set out in the Green Communities Act. National Grid achieved an overall energy reduction among all SES pilot participants (both active and passive) of 3.9% in 2015 and 7.2% in 2016. In addition, customers saved an average of $114 on their electric bills in 2015, for a cumulative savings $1.25 million (National Grid Media Relations , 2016) .

A success factor of National Grid's SES program was the consumer-focused demand response technologies adopted by 24.3% of SES customers by 2016. As shown below in Figure 7, active customers who adopted at least one of the levels of technologies achieved significantly higher rates of peak demand reduction than passive customers. Based on these findings it is clear that consumer-focused demand response technologies have had a significant impact on peak demand reduction for National Grid's SES program.



**Peak Event Load Reductions were statistically significant at the 90% confidence interval level among all groups in the figure above, except for Level 1 Passive for 2015.*

Figure 7 - SES Average Peak Load Reduction for CPP Customers by Technology (Navigant, 2016)

Increasing the Adoption of Demand Response Technologies

There is a clear relationship between customers adopting new demand response technologies and a reduction in energy usage during times of peak demand. However, as shown in Figure 8 below in 2016 only 24.3% of SES customers had adopted any of the program's technologies and only 8.8% had adopted any of the in home technologies (technology levels 2 – 4). Given the low technology adoption rates by SES customers, this begs the question of why didn't SES customers adopt the technologies available to them? In addition, how can National Grid and other utilities encourage increased adoption of these consumer-focused demand response technologies that have a significant impact on peak demand reduction? This report will seek answers to these questions so that National Grid and other utilities have the information necessary to increase the adoption of these technologies and reduce peak demand.

Technology Level Adoption among National Grid SES Customers on CPP rate in 2016

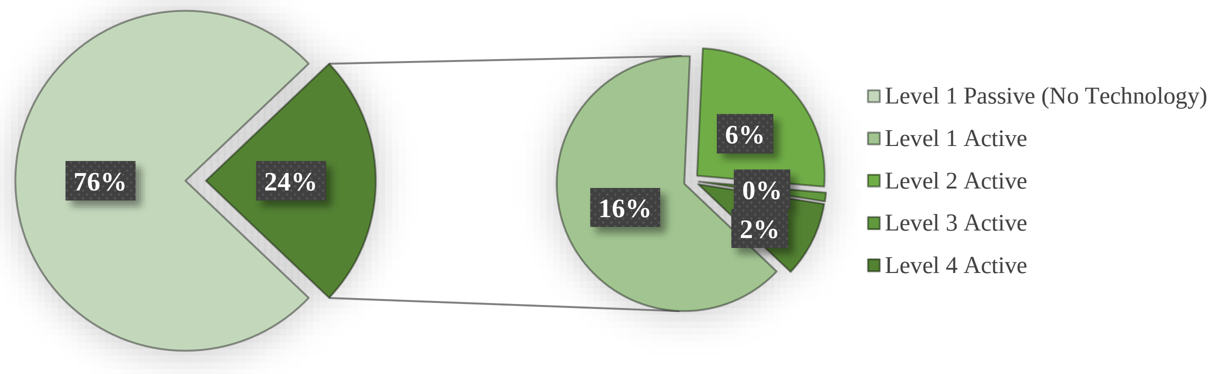


Figure 8 - Technology Level Adoption among National Grid Customers on CPP rate in 2016 (Navigant, 2016)

Economic Incentive for Consumer-Focused Demand Response Technologies

Another key consideration for the SES program is cost savings for customers broken down by technology level. Figure 9 below shows that SES customers across all technology levels achieved cost savings over the first nine months of the pilot. Two main factors may have contributed to these savings: 1) having a time based rate structure led to greater savings most months of the year, 2) technologies helped SES customers achieve higher levels of cost savings. The program resulted in cost savings for all SES customers, with greater savings for those who adopted technologies.

National Grid SES customer Bill Savings from January - September 2015

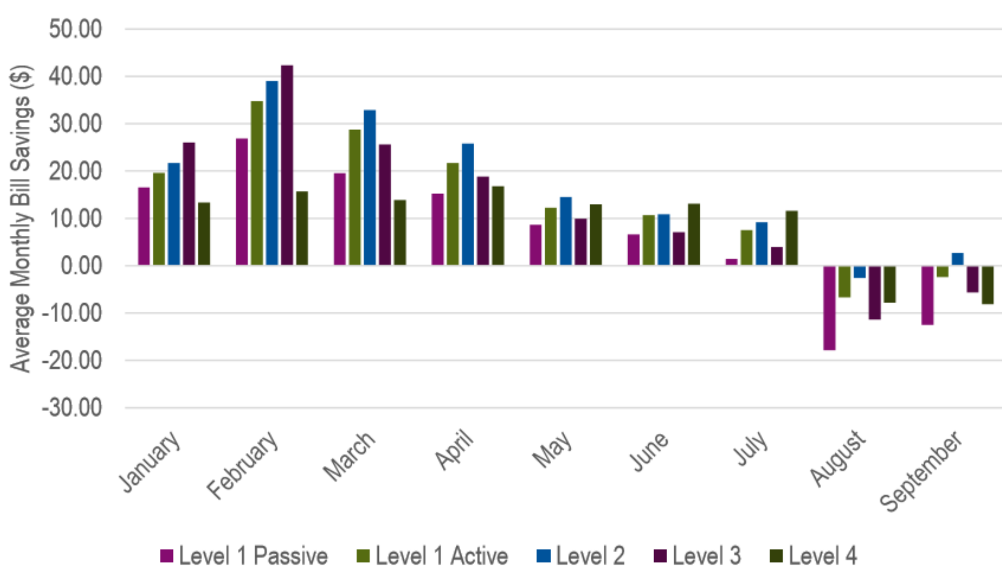


Figure 9 - National Grid SES customer Bill Savings from January - September 2015 (Navigant, 2015)

Table 3 below shows that National Grid SES customers who adopted at least one of the levels of technology saved more on their electric bills than customers who did not adopt any type of technology. Interestingly, Level 2 customers achieved the highest bill savings below despite having lower rates of peak demand reduction than either Level 3 or 4 customers (See Table 3 and Figure 7).This is because Level 2 customers achieved higher overall energy demand reductions than any of the other technology groups as shown in Figure 10. This is an important finding to highlight. Even though the Level 2 technology, IHDs, did not achieve as high a peak demand reduction as other technologies, it was more effective at reducing overall energy demand and therefore was able to save customers more through the first nine months of the SES pilot in 2015. Moving forward this is an important factor for National Grid and other utilities be aware of and consider; different technologies appear to have different impacts on reducing peak demand versus overall energy demand. Depending on the goals of the program, different types of technologies may be more effective than others.

National Grid SES Customer Bill Savings January - September 2015 by Technology Level					
	Level 1 Passive	Level 1 Actice	Level 2	Level 3	Level 4
Cost Savings	$ 64	$ 126	$ 154	$ 117	$ 81
Difference from Level 1 Passive	$ -	$ 62	$ 90	$ 53	$ 17

Table 3 - National Grid SES Customer Bill Savings January - September 2015 by Technology Level (Navigant, 2016)

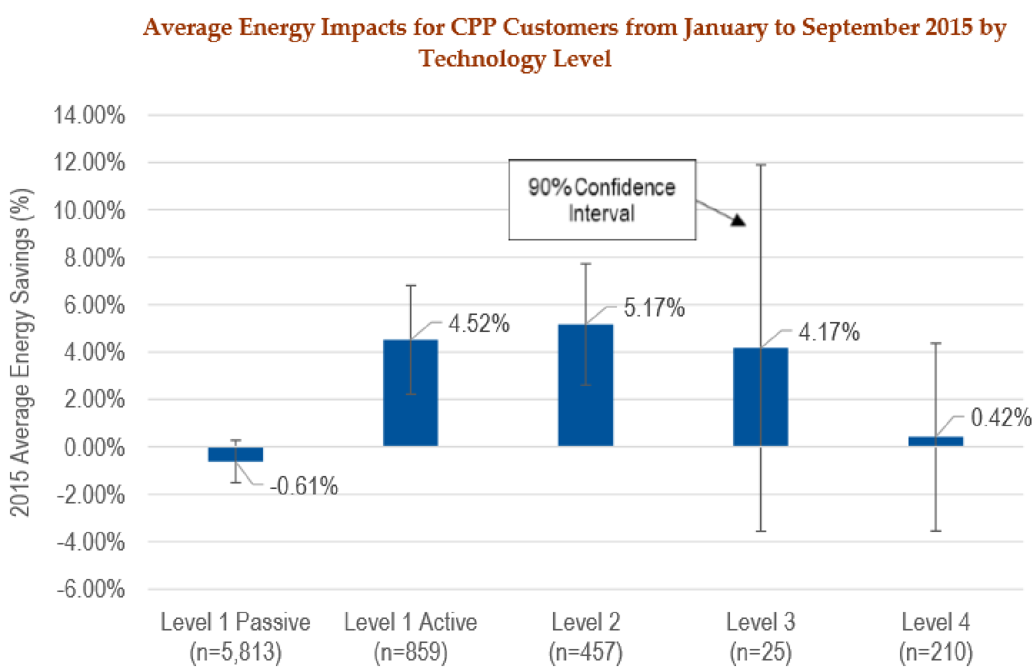


Figure 10- Average Energy Savings for CPP Customers from January to September 2015 by Technology Level (Navigant, 2015)

Important Information about Bill Savings and Energy Impacts

For this report, peak demand savings for the entire two years of National Grid's SES program from 2015-2016 has been analyzed by Navigant because the final peak demand event took place in September 2016. However, the analysis of bill savings and energy impacts for all of 2015 – 2016 has not yet been completed by Navigant and is therefore unavailable for analysis in this report. Included above are the bill savings and energy impacts from the first nine months of the 2015 as provided by Navigant in their SES pilot Interim Evaluation Report in 2016.

Benchmarking Against Other Smart Grid Programs

Before examining the barriers to the adoption of demand response technologies in smart grid programs it is important to first benchmark National Grid against similar smart grid programs across the country.

Methodology

This section of analysis was based on information identified in the U.S. Department of Energy's "Final Report on Customer Acceptance, Retention, and Response to Time Based Rates from the Consumer Behavior Studies" (hereafter referred to as DOE Final Report) (DOE, 2016). Results were analyzed from smart grid pilot programs based on peak demand reductions and technology acceptance rates to produce key findings for National Grid and other utilities.

Overview of Smart Grid Programs

Figure 11 below comes from Navigant's 2016 Impact Evaluation Update and shows that average, maximum and minimum peak demand reductions achieved during peak events by National Grid's SES technologies were comparable to other utilities' smart grid program technologies.

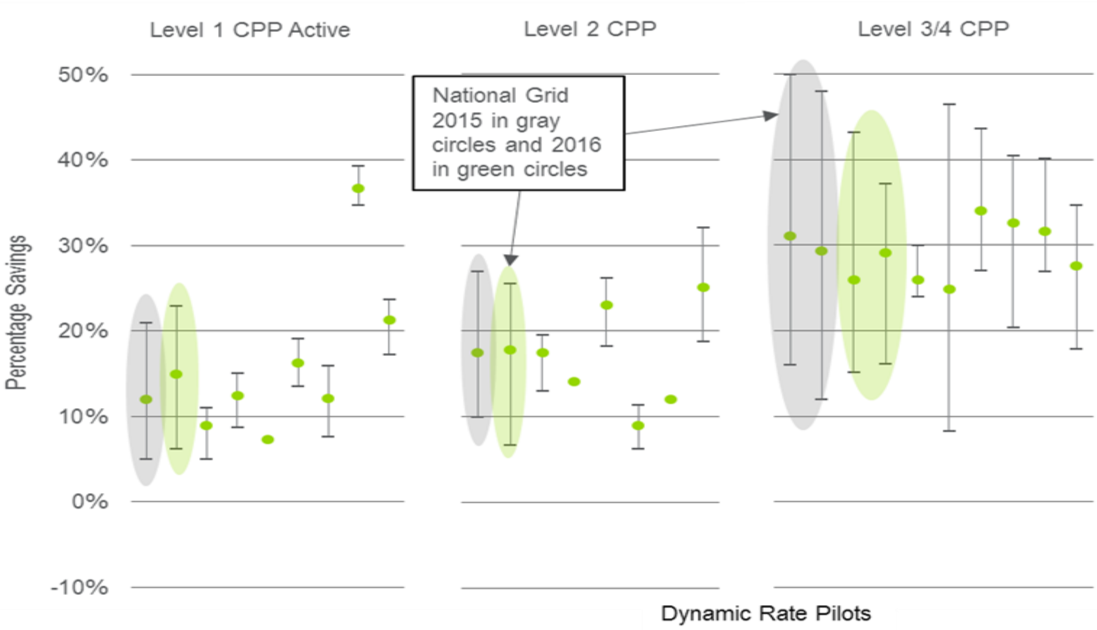


Figure 11 - Residential Peak Event Impacts Compared to Other Utilities (Navigant, 2016)

* "The comparisons include the average, maximum, and minimum impact when possible, or the average impact when the minimum and maximum could not be found. The comparisons are grouped by the Pilot's technology/price groups, and the comparison programs are matched to the Pilot groups based on the descriptions of the price plans and the enabling technologies in the comparison program's report" (Navigant, 2016, pg 47)

Utility Comparisons: Eversource (NSTAR), Cleveland Electric Illuminating Company (CEIC), DTE Energy (DTE), Green Mountain Power (GMP), Marblehead Municipal Light Department (MMLD), Oklahoma Gas and Electric (OG&E), Sacramento Municipal Utility District (SMUD).

After comparing peak demand reduction rates by technology, it is also important to compare the adoption rate of these technology levels across different utilities' smart grid programs. However, because no smart grid program is structured and implemented in the same way, drawing comparisons between different programs can be challenging. Different smart grid pilot programs use different time based rate structures (TOU, CPP, PTR, etc.), demand response technologies (IHDs, PCTs, etc.) and customer enrollment options (Opt-in vs. Opt-out programs). The most comprehensive source of information and analysis of smart grid programs available comes from the Department of Energy's Final Report on Customer Acceptance, Retention, and Response to Time Based Rates from the Consumer Behavior Studies. This report was conducted by the Smart Grid Investment Grant Program (SGIG) through the U.S. Department of Energy (DOE). The SGIG partnered with ten different electric utilities to conduct consumer behavior studies. The purpose of this comprehensive report was to produce a "robust and credible analysis" of the benefits, costs, and impacts of these smart grid programs to assist utilities for future smart grid investments (U.S. Department of Energy, 2016).

Table 5 below breaks down the ten smart grid pilot programs analyzed in the DOE's Final Report by their rate treatment (i.e., rate structures), non-rate treatments (i.e., types of technology and education) and by the recruitment approach (i.e., whether the program was Opt-Out or Opt-In). In the case of National Grid, the program was a combination of TOU/CPP rate structures, utilized IHD and PCT technology, and was an Opt-Out program. The difference between Opt-In and Opt-Out programs is essential to understand. The rate of technology adoption would be assumed to be higher among those in an Opt-In program than an Opt-out program. This is because customers who have already taken action to join the rate plan are more likely to acquire the technology.

	CEIC	DTE	GMP	LE	MMLD	MP	NVE	OG&E	SMUD	VEC
Rate Treatments										
CPP		●	●		●	●	●	●	●	
TOU		●		●		●	●	●	●	
VPP								●		●
CPR	●		●							
Non-Rate Treatments										
IHD	●	●	●					●	●	
PCT	●	●					●	●		
Education							●			
Recruitment Approaches										
Opt-In	●	●	●	●	●	●	●	●	●	●
Opt-Out				●					●	
Utility Abbreviations: Cleveland Electric Illuminating Company (CEIC), DTE Energy (DTE), Green Mountain Power (GMP), Lakeland Electric (LE), Marblehead Municipal Light Department (MMLD), Minnesota Power (MP), NV Energy (NVE), Oklahoma Gas and Electric (OG&E), Sacramento Municipal Utility District (SMUD), Vermont Electric Cooperative (VEC)										

Table 4 - Smart Grid Pilot Programs (U.S. Department of Energy, 2016)

Within this report, Sacramento Municipal Utility District (SMUD)'s pilot was the program chosen for benchmarking against National Grid in most cases. There were two principal reasons for this. First, SMUD is the program that the DOE Final Report provided the most comprehensive data and analysis on. Second, SMUD is also the program which most closely aligned with National Grid because it also utilized an Opt-Out approach, had a similar TOU/CPP rate structure, and used IHDs. In addition to benchmarking against SMUD, the report also draws on analysis provided by the DOE in its Final Report which takes all ten smart grid pilot programs analyzed into account. Below are some of the key findings from the DOE Final Report, SMUD's Smart Pricing Options Final Evaluation, and analysis of National Grid's SES program.

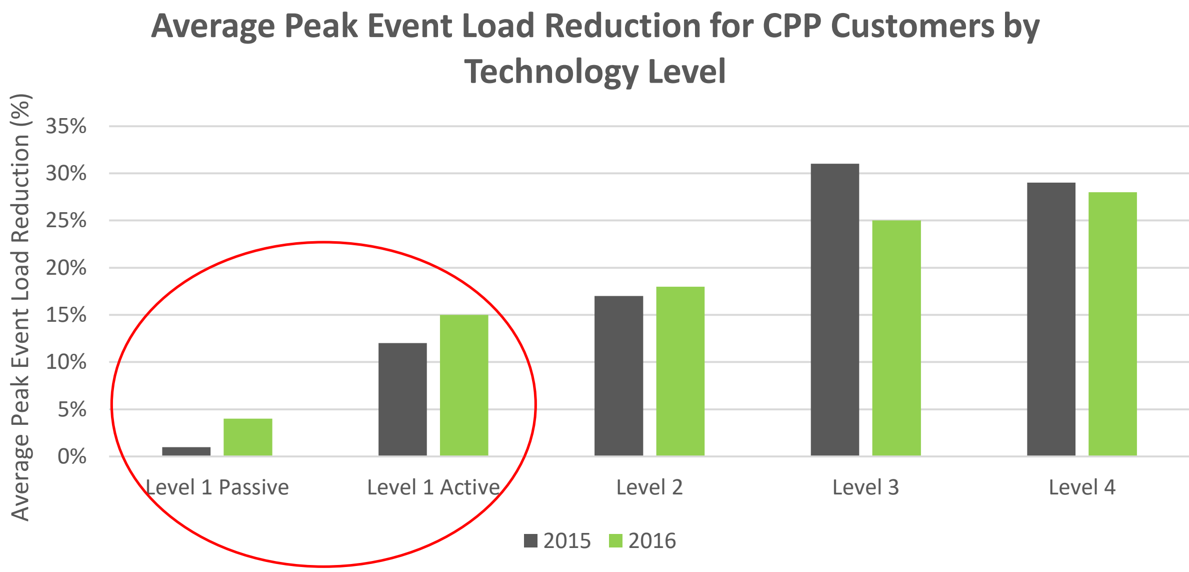
Finding 1) – Web Portals

The widespread adoption of web portals in smart grid pilot programs indicates that they likely are effective but lack of data to evaluate them does not make this certain.

All smart grid pilot programs evaluated by the U.S. Department of Energy (DOE) have a web portal. However, no program examined in the DOE's Final Report "established treatment and control groups to evaluate their efficacy on customer enrollment, retention, or response" (U.S. Department of Energy, 2016, pg 46). While the widespread adoption of web portals among smart grid pilot programs indicates that web portals are most likely effective in reducing peak demand, this conclusion is not a certainty.

Both the SMUD and National Grid programs utilized web portals. However, National Grid established a control group with the Level 1 CPP passive customers and a testing group with the Level 1 CPP active customers.[2] The 1 Level CPP active group had statistically significant reductions in peak demand as reported in Navigant's 2016 demand response impacts report and seen below in Figure 12.

[2] The difference between Level 1 CPP passive SES customers and Level 1 CPP active SES customers is that passive customers never accessed their online web portal and active customers accessed their online web portal at least once.



**Peak Event Load Reductions were statistically significant at the 90% confidence interval level among all groups in the figure above, except for Level 1 Passive for 2015.*

Figure 12 - SES Average Peak Load Reduction for CPP Customers by Technology (Navigant, 2016)

Finding 2) – In-Home Devices (IHDs)

The effectiveness of IHDs on reducing peak demand is inconclusive and the offer of IHDs negatively impacts benefit-cost ratios.

The DOE's Final Report found that the capabilities of IHD devices to affect peak demand reduction was inconclusive and that further study and analysis needs to be done to fully assess the effect of IHDs (U.S. Department of Energy, 2016). SMUD's pilot program found no evidence from their results that IHDs significantly increased peak load reductions (U.S. Department of Energy, 2016). Figure 13 below shows that although there were slightly higher peak demand reductions among SMUD customers who had IHDs than those who did not, once pre-treatment[3] differences were taken into account, there was no measureable effect of IHDs on SMUD's peak demand reductions. (U.S. Department of Energy, 2016). SMUD's report further concluded that while "IHDs were correlated with slightly higher retention rates (1-4 percentage points) and boosted the magnitude of demand reductions by 2-4 percentage points, the costs of the devices were large enough to offset the majority of the additional benefits the IHDs generated" (U.S. Department of Energy, 2015, pg 46).

[3] Pre-treatment refers to the period prior to the start of the two year smart grid pilot program.

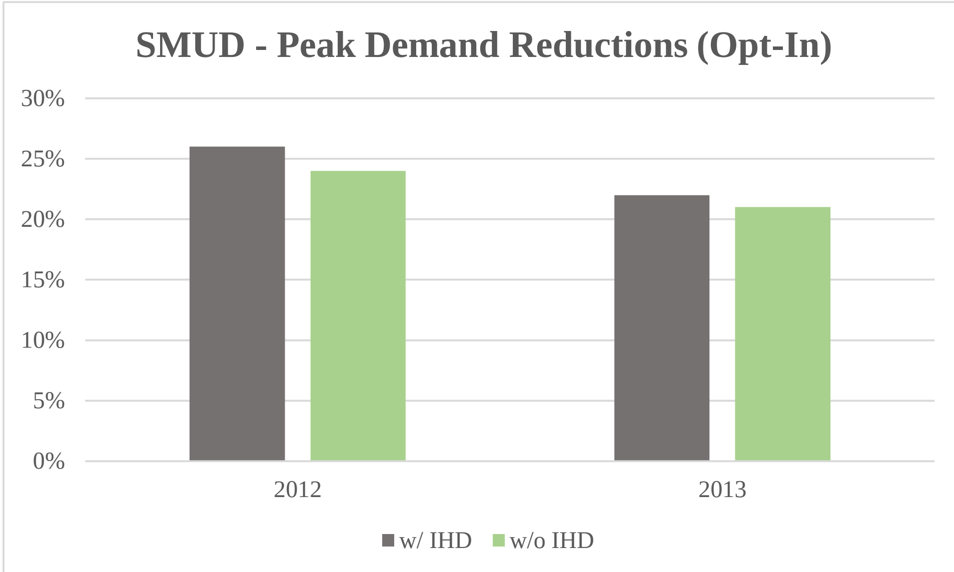


Figure 13 - SMUD IHD Peak Demand Reductions (U.S. Department of Energy, 2016, pg 50)

Table 6 below is a benefit-cost analysis from SMUD's smart grid pilot program's final report. Of particular note are the default sections towards the bottom of the table which highlight the differences between offers of technology to Opt-Out TOU-CPP customers vs. no offers of technology to Opt-Out TOU-CPP customers. The benefit-cost ratio for those offered technology is 2.49, but among those not offered technology (simulated) the benefit-cost ratio increases to 4.53, showing that not offering IHDs significantly increased the benefit-cost ratio.

Scenario Type	Scenario	Benefit/Cost Ratio	10 Year NPV for SMUD Territory		
			Benefits	Costs	Net Benefits
Opt-in Tested	TOU, No IHD Offer	1.19	$12.1	$10.2	$2.0
	TOU, IHD Offer	0.74	$15.5	$21.0	-$5.5
	CPP, No IHD Offer	2.05	$29.7	$14.4	$15.2
	CPP, IHD Offer	1.30	$34.3	$26.3	$7.9
Default Tested	TOU, IHD Offer	2.04	$66.9	$32.8	$34.1
	CPP, IHD Offer	2.22	$142.1	$63.9	$78.2
	TOU-CPP, IHD Offer	2.49	$144.8	$58.1	$86.7
Default Simulated	TOU, no IHD Offer	4.48	$66.9	$15.0	$52.0
	CPP, no IHD Offer	4.28	$142.1	$33.2	$109.0
	TOU-CPP, no IHD Offer	4.53	$144.8	$32.0	$112.9

Table 5 - SMUD Benefit-cost Analysis (Nexant, 2014, pg 118)

Not all programs reached the same conclusion about their IHDs. Green Mountain Power, based in Vermont, found that demand reductions from CPP customers with IHDs were statistically significant. In Table 7 below the rows CPP-CPP and CPP-CPP w/IHD show the impact IHDs had on reducing energy demand. By looking at the “During” column we can see that in both 2012 and 2013, load reductions during peak events for customers with IHDs were statistically significant. However, unlike SMUD’s smart grid program, the GMP smart grid program did not have a benefit-cost analysis of their IHD program, only overall reductions.

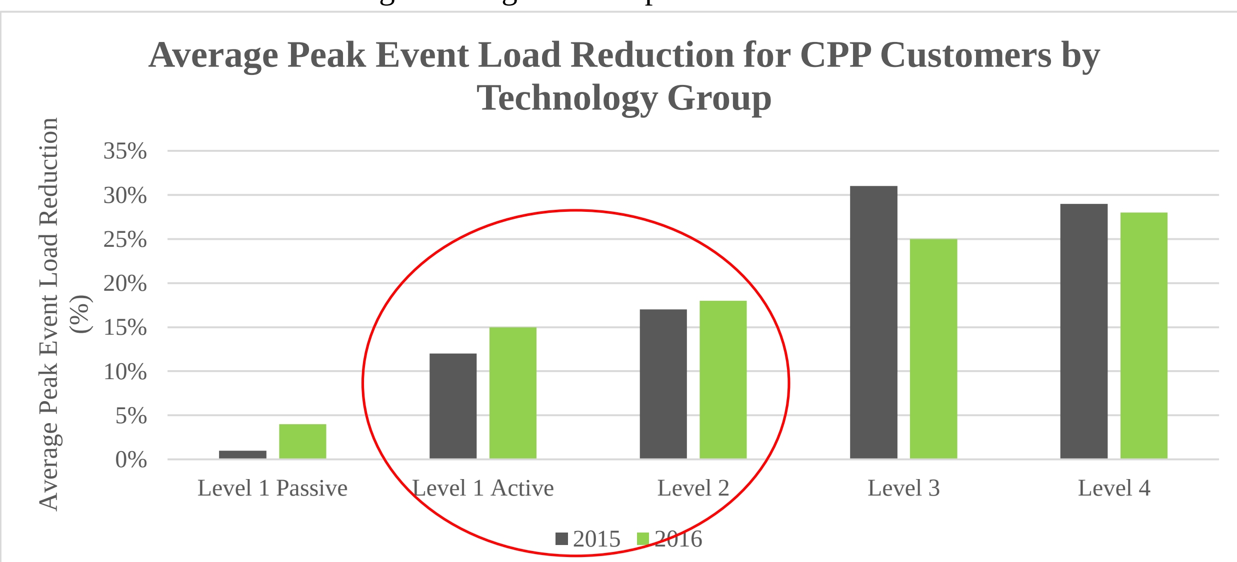
Summary of load impacts (percentage reductions relative to the no-notification control group), 2012 and 2013

	2012			2013		
Treatment	**Before**	**During**	**After**	**Before**	**During**	**After**
Flat Rate w/ Notification	-6.45%	-3.38%	*0.15%*	-3.81%	-8.18%	-5.81%
CPR-CPR	-4.72%	-5.29%	*-0.57%*	1.06%	-2.17%	*-1.52%*
CPR-CPR w/IHD	-2.65%	-7.64%	*3.41%*	2.41%	-9.55%	-5.77%
CPP-CPP	-1.51%	-7.42%	1.77%	-0.56%	-7.46%	-3.79%
CPP-CPP w/ IHD	-8.67%	**-11.80%**	*2.68%*	3.56%	**-14.48%**	-0.67%
CPR-CPP	-4.29%	-8.57%	*-1.27%*	**16.86%**	1.40%	1.90%
CPR-CPP w/ IHD	-5.29%	-6.24%	*-4.40%*	1.82%	-16.40%	-3.43%

**Numbers in bold were statistically significant at the 95% confidence interval level or better.*

Table 6 - GMP Peak Demand Impacts (Blumsack, Hines, 2015)

For National Grid’s program, the findings in Figure 14 below show that there is a statistically significant difference between Level 1 CPP active customers and Level 2 CPP customers. (12% vs. 17% in 2015 and 15% vs. 18% in 2016). Although peak demand reduction rates are higher among those with IHDs, there has been no benefit-cost analysis to determine the benefits and costs of achieving these high rates of peak demand reduction.



**Peak Event Load Reductions were statistically significant at the 90% confidence interval level among all groups in the figure above, except for Level 1 Passive for 2015.*

Figure 14 - SES Average Peak Load Reduction for CPP Customers by Technology (Navigant, 2016)

	Peak Demand Reductions	
National Grid	Year 1 (2015)	Year 1 (2016)
Level 1 CPP (Without IHD)	12%	15%
Level 2 CPP (With IHD)	17%	18%
Impact of IHD	**5%**	**3%**
SMUD	Year 1 (2012)	Year 2 (2012)
Opt-In CPP (Without IHD)	22%	21%
Opt-In CPP (With IHD)	26%	24%
Impact of IHD	**4%**	**3%**
GMP	Year 1 (2012)	Year 2 (2013)
CPP-CPP (Without IHD)	7.4%	7.5%
CPP-CPP w/IHD (With IHD)	11.8%	14.5%
Impact of IHD	**4.4%**	**7.0%**

Table 7 - Peak Demand Percentage Reductions (Navigant, 2016;SMUD, 2014;Blumsack, Hines,2015)

Table 8 above compares the peak demand reductions achieved by IHDs from three smart grid pilots, National Grid, SMUD, and GMP. The takeaway from the DOE's Final Report, and findings from National Grid, SMUD, and GMP is that smart grid programs across the country, including National Grid, should closely examine the impact of their IHDs on peak demand and determine their benefit-cost value. One key aspect to consider for a benefit-cost analysis is to not only include the immediate benefits and costs of the program but also include future cost savings from limiting future demand and potential expansion of the grid.

Finding 3) – Programmable Communicating Thermostats (PCTs)
PCTs significantly reduce peak demand and positively impact benefit-cost ratios

The Department of Energy's analysis of ten smart grid pilot programs found that "peak demand reductions were substantially higher" when PCTs were offered. In addition, in contrast to IHDs, benefit-cost ratios for PCT offers were positive (U.S. Department of Energy, 2016). Based on the success of PCTs in their pilot program, Oklahoma Gas & Electric (OG&E) decided to roll-out a time-based rate with an offer of a free PCT to all of their residential customers with a recruitment goal of 120,000 customers within three years. (U.S. Department of Energy, 2016)

SMUD's pilot program did not offer PCTs so there is no information available for them. However, in the case of National Grid, PCTs were offered. Table 9 below shows the peak demand reduction impact of PCTs in 2015 and 2016 and accounts for reductions from the web portal. Adding a PCT substantially increased peak demand reduction, although it should be noted that the impact of PCTs from 2015 to 2016 decreased. Moving forward, National Grid should continue to monitor the impacts of its PCTs.

	National Grid SES Peak Demand Reductions	
	2015	2016
Level 1 CPP Active (Web Portal only)	12%	15%
Level 3 CPP (Web Portal and PCT)	31%	25%
Impact of PCT	**19%**	**10%**

Table 8 - National Grid SES Peak Demand Reductions (Navigant, 2016)

The takeaway from the DOE's Final Report, and findings from National Grid is that PCTs should be included in smart grid pilot programs because findings show they have a statistically significant impact on reducing peak demand positively impact benefit-cost ratios.

Barriers to the Adoption of Smart Grid Demand Response Technologies

Overview

For utilities, there are numerous challenges to the adoption of consumer focused demand response technologies, including informing customers about the technologies, demonstrating their effectiveness and usefulness, and ensuring that customers continue to utilize these technologies. Other challenges include determining what percentage of customers have an internet connection and what percentage have central air conditioning. This section of the report identifies barriers to the adoption of consumer-focused demand response technologies and gives recommendations to overcome these barriers.

Methodology

Within this section, results from National Grid's SES program are analyzed and compared against other smart grid programs. This section examines smart grid, demand response technologies through a framework of "barriers" which prevent consumers from adopting these technologies. Barriers can be divided into two categories - structural and psychological**.**

Structural Barriers refer to an impediment to technology adoption that typically is physical and that the utility has limited ability to directly influence. Structural barriers addressed in this report include: a home not connected to the internet, no central air conditioning, not having control over a household's thermostat, having a different supplier of energy, etc. Even though a structural barrier may be outside of the control of a utility, by identifying and benchmarking these barriers, they can be better addressed.

Psychological Barriers refer to an impediment to technology adoption that reside within the consumer and that the utility has a greater ability to directly influence. Psychological barriers addressed in this report include: being unaware of these technologies, perceiving the technology as not useful, perceiving the technology as not easy to use, having difficulty acquiring the technology, not continuing to use the technology once adopted, etc.

Structural Barriers

Alternative Energy Supplier

Fifteen states across the country, including Massachusetts, have deregulated retail power markets (U.S. Energy Information Administration, 2010). This means that consumers in these states have the right to buy electricity from a company other than the utility which distributes electricity to their home. Within the National Grid SES pilot program, a significant portion of customers were unable to participate because they have alternate suppliers of electricity besides National Grid that have different rate plans. Therefore, these customers were unable to enroll in the SES pilot program's SRP or CDR rate plans. Within National Grid's SES pilot program, 14,661 smart meters were installed in Worcester prior to the initiation of the pilot. However, of these 14,661 customers, 2,750 (18.6%) were ineligible to participate in the program once it began on January 1, 2015 because they had another supplier of electricity (Jones, 2015).

Internet Access

For National Grid's SES's program, these demand response technologies require access to the internet, which prevents a portion of SES customers from using the technologies. This section of the paper seeks to clarify what percentage of Worcester residents could not use these technologies because of a lack of access to the internet. National Grid conducted a pre pilot survey in 2014 among 1,470 future SES customers. One of the questions asked was: *Does this residence currently have an internet connection in your home*? (Navigant, 2014). Approximately 89% of respondents answered "Yes." This data suggests that nearly 90% of Worcester residents have internet access in their homes and therefore should be able to use the SES program's demand response technologies. However, the survey respondents may not be representative of the population as a whole. Further, asking whether a home has an internet connection does not necessarily mean that the home is using that internet connection. Therefore, these survey findings may have somewhat overestimated the proportion of SES customers with homes connected to the internet.

Data from the U.S. Census Bureau's 2014 American Community Survey (ACS) in Table 10 below provide estimates for the number of households with a computer AND with an internet subscription. ACS estimated that only 72.5% of Worcester households have a computer and internet subscription.

Percent of households with a computer and an internet subscription					
United States		Massachusetts		Worcester City, Massachusetts	
Estimate	Margin of Error	Estimate	Margin of Error	Estimate	Margin of Error
76.7%	0.1%	82.4%	0.6%	**72.5%**	4.1%

Table 9 - Percent of Households with a computer and an internet subscription (U.S. Census, American Community Survey, 2014)

Findings from the Pew Research Center 2016 survey support the U.S. Census ACS estimates. Figure 16 below shows that 13% of America adults replied that they never access the internet (Anderson & Perrin, 2016). In addition, in Figure 15 below, another Pew Research Center survey found that 19% of American adults have no broadband service available at home other than a smart phone data plan AND/OR they have limited options for online access other than a smart phone (Smith, 2015). An estimated 27.5% of residents in Worcester could not access the internet in 2014 and therefore, it is possible that over 25% of pilot participant could not have accessed National Grid's SES technology offerings. In addition, findings from Pew Research Center show that a significant portion of Worcester's population may have limited access to the internet other than through their smart phone, assuming they even have one. Moving forward National Grid and other utilities need to be aware of these limitations in internet access among significant portions of the population when developing and deploying their demand response technologies.

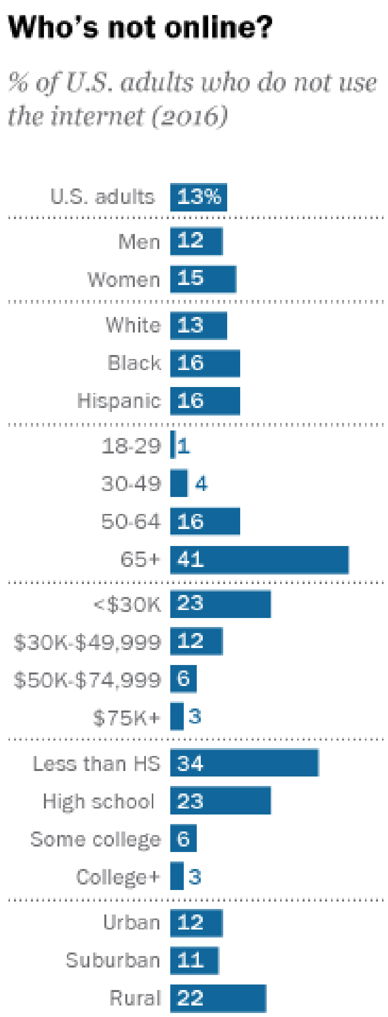


Figure 16 - American Adults Not Online (Anderson, M., & Perrin, A, 2015)

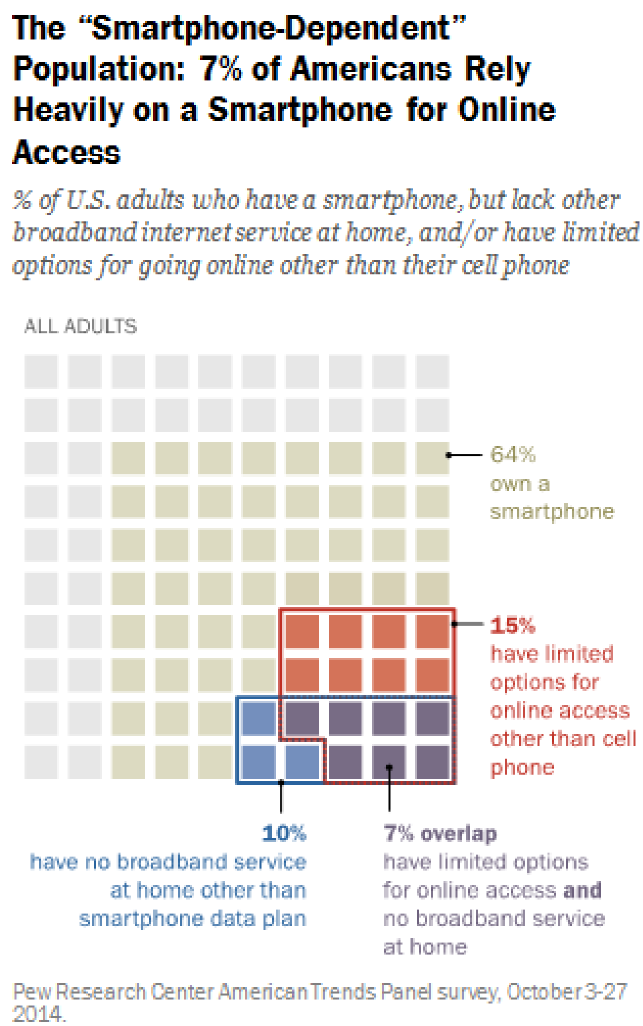


Figure 15 - Smart Phone Use (Smith, A, 2015)

Central Air Conditioning

One of the most impactful ways to reduce electricity use during times of peak demand is through PCTs. Although there are variations based on geography, in many parts of the country the highest demand placed on the electric grid takes place during summer, particularly on hot, humid days. The Independent System Operator of New England (ISO-NE) who oversees New England's electric grid, sees a strong link between heat waves, air conditioning use, and peak demand, stating "Peak demand is driven by weather, which drives the use of heating and air conditioning equipment." (ISO New England , 2016).

In the case of National Grid, all of the peak events called during the two years of the pilot program occurred between June 1st and September 30th and took place sometime between 12:00 PM and 8:00 PM (Navigant, 2017). The reason for this for this high strain placed on the grid often comes from utility customers turning up their air conditioners to cool their homes during hot summer days. Within New England the percentage of homes with central air conditioning is relatively low compared to the rest of the country. However, this percentage has increased in recent years and is projected to increase further in New England. In 2011, 24.5% of New England homes had central air conditioning and by 2015 that number had increased to 27.8% (U.S. Census Bureau, 2015). While this may not seem like a big increase this equates to an annual growth rate of 3.2% in homes with central air conditioning in New England. Simply put, the percentage of homes with central air conditioning has been increasing at a steady rate over the past four years and given the increase in summer high temperatures from climate change, this growth will continue or even accelerate.

PCTs require homes to have central air conditioning and need a connection and wifi unless a gateway is used. Data from the U.S. Census, a National Grid survey and the City of Worcester in Table 10 below show what percentage of residences in Worcester have central air conditioning.

	Percent of Residential Households in Worcester with Central Air Conditioning
U.S. Census for New England (2015)	27.8%
National Grid Pre Pilot Survey Results (2014)	33%
Worcester City Government (2016)	11.4%

Table 10 - Percent of Residential Houses in Worcester with Central Air Conditioning (U.S. Census, 2015) (Worcester City Government, 2016) (Navigant, 2014)

Navigant's 2014 pre-pilot survey asked customers if they have central air conditioning in their residence and 30% answered "Yes" (Navigant, 2014). An additional 3% responded that they did have central air conditioning but that it was included in either their rent or condo fee. This is an important distinction to make as it eliminates the financial incentive for 3% of customers to reduce their energy usage. The Worcester City government data provided may be the most surprising finding. More research is needed to determine the actual percentage of SES customers who have central air conditioning in Worcester. Moving forward National Grid and other utilities should be aware of the rapid growth rate of central air conditioning across the country and in New England, along with the significant impact that PCTs can have on reducing peak demand.

Additional Structural Barriers

Another structural barrier not discussed in detail in this report is that some customers may be renters and may not have control over whether or not they can install a new PCT in their building. This represents another structural barrier, specifically to the installation of PCTs. Navigant's analysis of their 2016 end of pilot survey cites one frequently given reason as to why more customers did not sign up for an in-home technology was because they weren't the property owner and believed that they couldn't install a PCT without the permission of their landlord (Navigant, 2016).

Summary

Having a different energy supplier, no or limited internet access, and a lack of central air conditioning all create obstacles to the adoption of consumer-focused demand response technologies. In the case of internet access and central air conditioning, these barriers also most likely disproportionally affect low income residents. Moving forward National Grid and other utilities can seek to overcome these barriers by encouraging and promoting the development of technologies which are accessible to all customers.

Psychological Barriers

Psychological barriers refer to those which essentially lie within the mind of the customer and may be directly addressed by the utility in some way. When considering psychological barriers, a useful framework is the "Hierarchy of Effects" (Lavidge and Steinger, 1961). The hierarchy of effects views the marketing of a product to consumers through three main stages. The first is "Thinking" where customers are made aware of the product and acquire basic knowledge (Awareness/Knowledge). The second stage is "Feeling" where customers who have a basic awareness and knowledge of the product analyze it to determine whether or not they like it, whether or not they think it is useful, and which variety of the product they might prefer to acquire (Liking/Preference). The third stage is what is known as "Doing" where customers decide they would like to acquire the product and then act to acquire it (Conviction/Purchase).

Figure 17 - Hierarchy of Effects (Mecca Marketing Invertate, 2011)

Another stage which is not included in this hierarchy but is still relevant is Loyalty. Loyalty refers to a customer's continued use of the product over time. This final stage is critical for the long term success of utility smart grid programs as utilities to need to rely on consistent and continued customer reductions in energy use.

Awareness & Knowledge

Assessing levels of awareness and knowledge of customers regarding customer-focused demand response technologies is extremely challenging because this is data which utilities are either not measuring or not making publicly available. Even more challenging than this is trying to assess the effectiveness of awareness marketing campaigns undertaken by utilities in regards to demand response. This is because the marketing of demand response technologies is often part of a much broader marketing effort around the smart grid program as a whole. Fortunately National Grid has survey data available indicating what portion of SES customers were aware that National Grid offers demand response technologies. This section gives an overview of the marketing efforts by National Grid to promote awareness of their demand response technologies.

Prior to the implementation of the SES program and throughout its initial stages, National Grid undertook extensive marketing to promote its demand response technologies including public events, mailings, and a door-to-door campaign. The Navigant Interim Evaluation report details National Grid's marketing efforts to encourage SES customer to change their energy habits and utilize the various technology levels as tools to help them achieve energy savings.

National Grid's end of pilot survey was conducted in 2016. One of the important points to note about surveys is that they are samples of the population as a whole. Figure 18 below shows that the proportion of respondents who had in home technology was significantly higher than among the sample group than among the SES population as a whole.

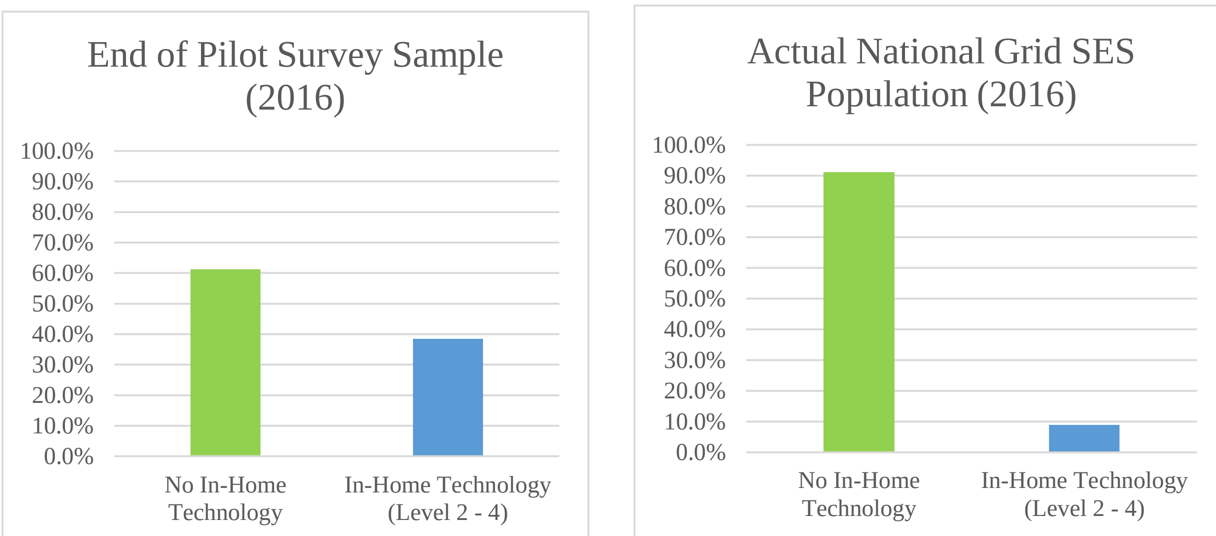


Figure 18 - Comparison of End of Pilot Survey vs. SES Population (Navigant, 2016)

Given this difference in the rate of technology adoption among the sample group and the SES population as a whole, any conclusions drawn from the survey results should be treated as tentative. It is possible that awareness levels of technologies may have been higher among the sample group than among the SES population as a whole. In National Grid's End of Pilot Survey, of the 379 SES customers surveyed who did not have an in-home technology, awareness of IHDs and PCTs was only 41%. Given that this percentage is from the sample and not the population as a whole, actual awareness of IHDs and PCTs among the entire SES population may actually be lower. Since awareness levels among SES customers in the sample group who did not have in home technologies was 41%, moving forward marketing and raising awareness should be a significant area of focus for National Grid in order to increase the adoption of demand response technologies.

Liking & Preference

Liking/Preference is the second step where customers determine whether or not they like the product and then determine what company they would prefer to buy from and what variety of the product they would prefer to purchase. In the case of National Grid and other utilities, customers can acquire demand response technologies through the utility's program or chose to acquire similar technologies from third parties such as companies. Assuming that customers chose to accept technologies from the utility, they may have a choice of which type of consumer-focused demand response technology to acquire.

The Technology Acceptance Model (TAM) describes how users come to accept and use a new technology (Davis, Bagozzi, & Warshaw, 1989). The first component customers consider to determine whether or not to adopt a new technology is their *Perceived Usefulness* of that technology. After customers are made aware of the technology and have a basic understanding of what it does, do they think it would be useful? The second component customers utilize to determine whether or not to adopt a new technology is their *Perceived Ease of Use* of that technology. After customers are made aware of the technology, have a basic understanding of what it does, and think it would be useful, do they believe it is easy to use?

National Grid's 2016 End of Pilot Survey provides data on what factors customers consider when deciding whether or not to acquire one of the technology offerings. By applying the TAM framework to some of the responses in this survey, a clearer picture can be seen for why National Grid customers who were made aware of these free technology offerings decided not to sign up for them. Figure 19 below provides answers chosen by SES customers who were aware of the in-home technologies but decided not to acquire them.

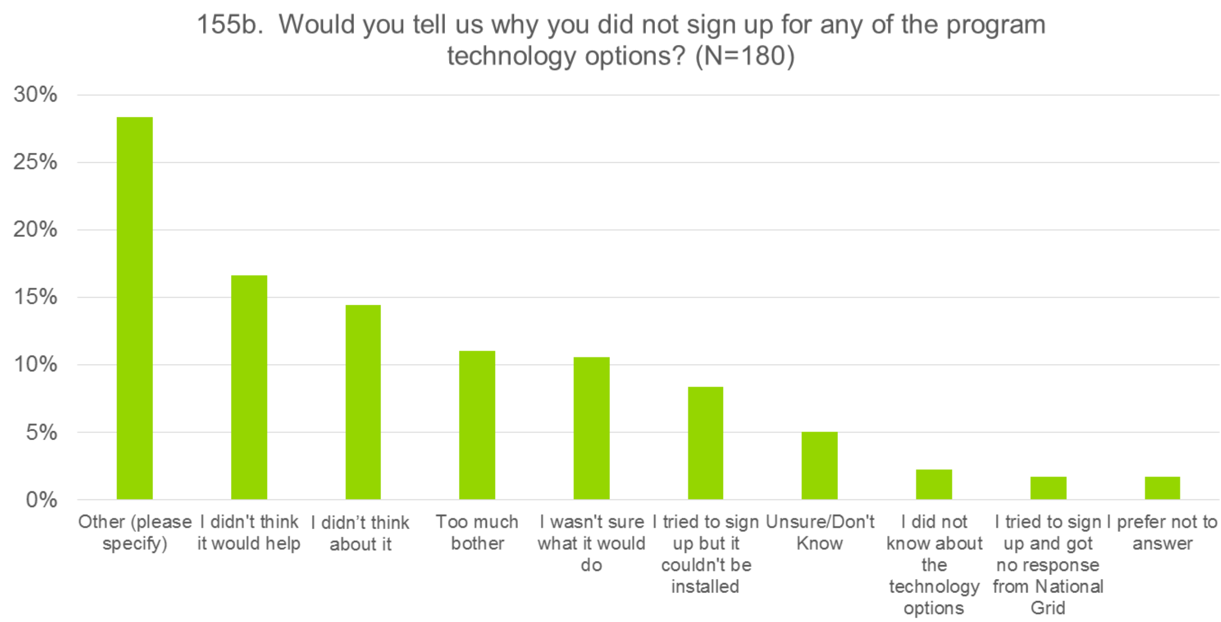


Figure 19 - Reasons for not signing up for demand response technology (Navigant, 2016)

"Other (Please Specify)" responses varied. Many responses indicated people weren't interested in the technology and that they were not the property owner and couldn't install thermostats without owner's permission.

Some of these answers are helpful in trying to determine why customers did not acquire these technologies. For example, 17 percent of respondents answered: *I didn't think it would help*, which indicates that they did not perceive the technologies to be useful to them. 11 percent of respondents answered that *I wasn't sure what it would do* which indicates that the information they received about the product did not provide them with sufficient knowledge about its use and purpose. These findings provide useful information for where National Grid can focus future marketing efforts and technology development.

However, other responses are more challenging to interpret. For example, the response: "*I didn't think about it"*. Does this response imply that customers knew about the technology but simply forgot about it? Also, the response: "*Too much bother"*. Does this mean that customers thought the device itself would be difficult to use? Or did they feel that the actual process of signing up for the device was "T*oo much bother*". In the future National Grid and Navigant should consider crafting responses which can more easily be interpreted.

For customers who signed up for National Grid's IHDs, a National Grid employee was sent to their home to show them how to operate the IHD. A survey of customers who received a picture frame asked: *Were the explanations sufficiently clear that you could operate all of the installed equipment?* (Navigant, 2015). In Figure 20 below, 98 percent of respondents said that the instructions were either very clear or sufficiently clear so they could operate the installed equipment. This indicates that the training of customers by National Grid employees to use these IHDs was effective. However, this question does not truly address the *Perceived Ease of Use* of the IHD. Just because customers have been trained and can effectively use an IHD does not mean that a device is necessarily easy to use. Moving forward, National Grid and Navigant should consider also crafting questions which focus more directly on customer perceptions as to the usefulness and ease of useful of their technologies.

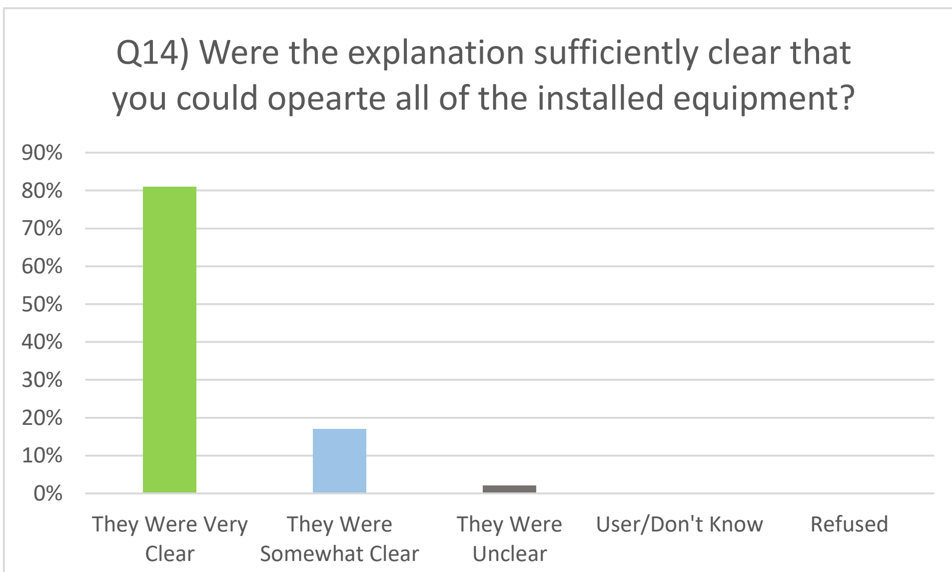


Figure 20 - Responses on explanations for operation of equipment (Navigant, 2015)

Motivations for Acquiring Demand Response Technologies

Apart from considering a technology's usefulness and ease of use, customers also have other motivating factors for deciding whether or not to acquire demand response technology. The data in Figure 21 comes from Navigant's pre-pilot survey and shows SES customer motivations for participating in the SES pilot program. Of particular note are the two bars on the left which indicate that climate change and the environment was just as significant of a motivator as saving money on an electric bill. As shown in Figure 22, SMUD asked their pilot participants to rank their largest motivations to save energy. Eighty percent of eligible pilot participants responded that saving money was their largest motivator. However, 10 percent listed protecting the environment as their largest motivator and other respondents listed broader societal concerns such as: For the general benefit of future generations and reducing our dependence on foreign oil.

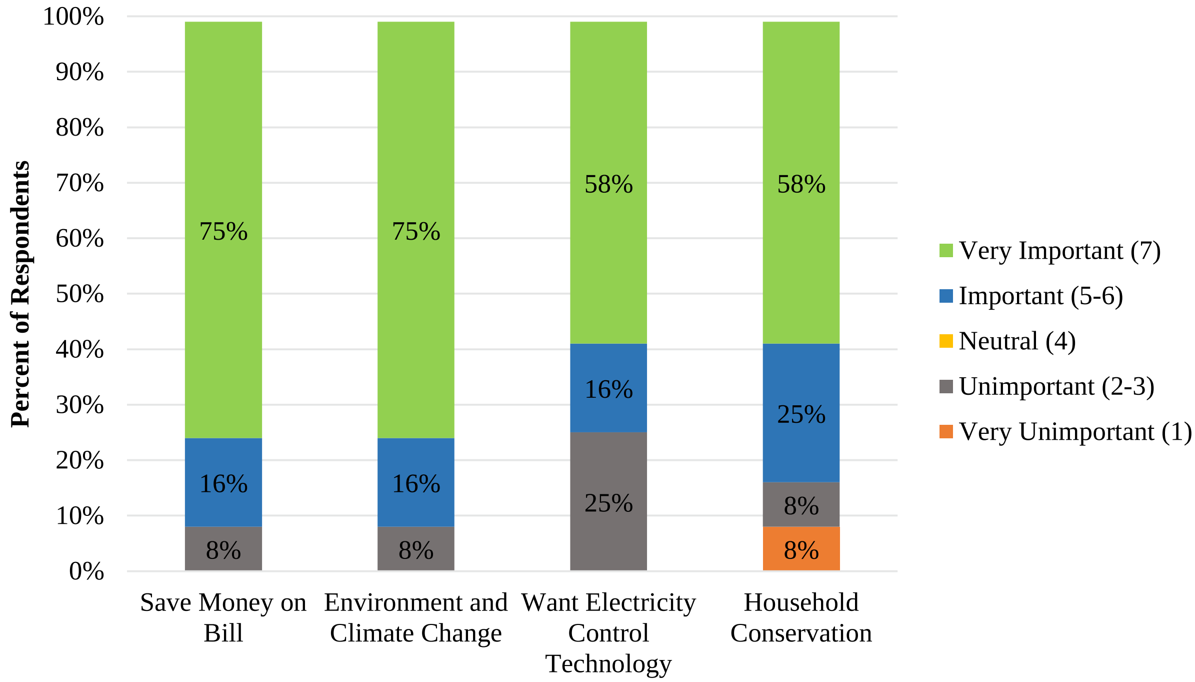


Figure 21 - Customer Motivations for Pilot Participation, Pre-Pilot Survey (Navigant, 2014)

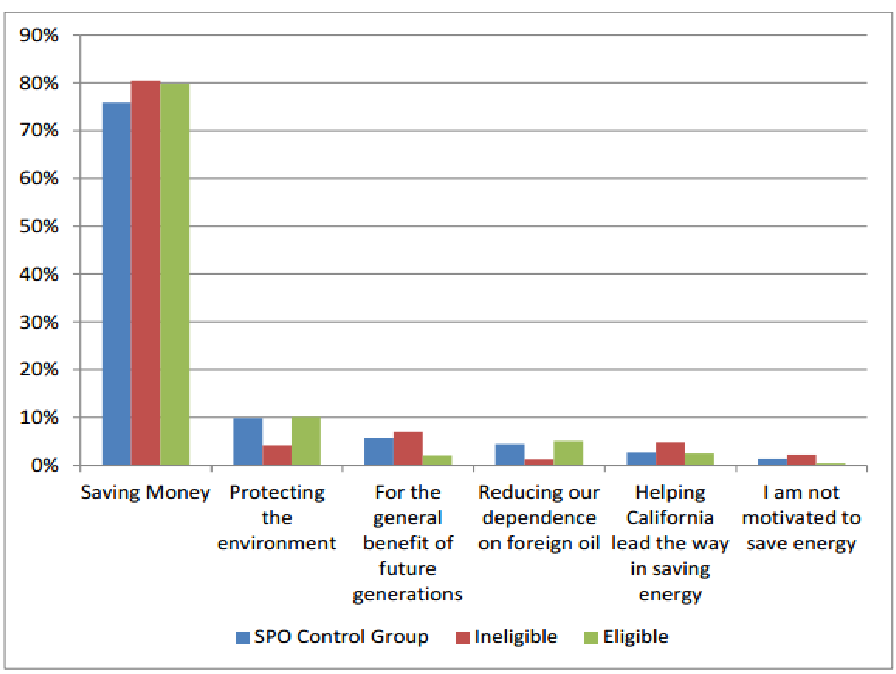


Figure 22 - SMUD Customer Motivations (Potter, G. J., 2015)

In addition to the National Grid and SMUD survey findings, the results of a 2014 study in Europe suggest that: "individuals are only likely to accept Smart Grid technology if they assess usefulness in terms of a positive impact for society and the environment". (Toft, Schuitema, & Thogersen, 2014). Taken together, these findings point towards utilizing environmental and societal messages in marketing for smart grid technology. Although neither National Grid nor SMUD's marketing materials highlighted the environmental benefits of the programs, moving forward these utilities and others should evaluate the value of including benefits to the environment and society in future marketing.

Conviction & Purchase

The third step in the Hierarchy of Effects is conviction and purchase when the customer has decided that they want to acquire the product and takes action to acquire it. For National Grid, this includes the 24.3% of active customers as of 2016 who have taken action to acquire one or more of National Grid's technology offerings. For this step, data is available to benchmark National Grid's adoption rate of IHDs against other utilities.

Table 12 below compares adoption rates of National Grid's IHDs against other smart grid pilot programs. National Grid performed on par with NSTAR's smart grid pilot program, which took place in Massachusetts from January 2013 – December 2014. However, SMUD achieved acceptance rates 2-3x higher for its Opt-Out programs than either NSTAR or National Grid. Reasons for SMUD's high acceptance rate may include: Having a slightly higher rate of households connected to the internet in Sacramento than Worcester (81.2% vs. 72.5%), having higher on peak and peak event rates charged to customers (3x On-Peak, 1.75x, Peak Event, Figure 23 below), and a very strong marketing effort.

Program	Acceptance Rate
National Grid SES	8.8%
NSTAR (Opt-In)	7%
SMUD Opt-Out programs	21% - 24%

Table 11 - IHD Acceptance Rates (Navigant, 2016, SMUD,2014 Navigant, 2015)

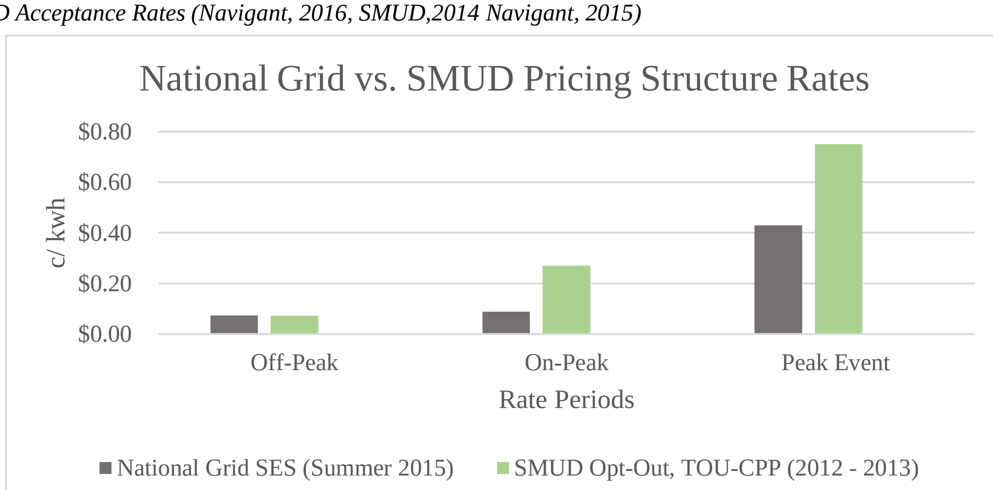


Figure 23 - National Grid and SMUD Pricing Plans (SMUD, 2014, Navigant, 2015)

According to the SmartGrid Consumer Collaborative, SMUD created an extensive marketing campaign with utilized various channels including: "social networks, online games, infographics, email, direct mail, YouTube videos, and dedicated websites loaded with information and interactive graphics on energy use" (Smart Grid Consumer Collaborative, 2016, pg 2). Internet access, cost differences, and marketing are some of the possible reasons SMUD achieved significantly higher rates of IHD adoption when compared to National Grid and NSTAR.

Loyalty

Just as important as benchmarking acceptance rates of demand response technologies is gathering data on what percent of customers continue to utilize the technology. If a customer acquires an IHD or PCT but never uses it, then the acquisition of the technology does not have an impact. Perhaps even more important than this is a customer's pattern of behavior in regards to energy consumption. Do customers have to continue to utilize a demand response technology for it to be effective? Does continuing to use a demand response technology no longer matter after a certain point in time once a customer's energy consumption behavior has been changed? If this is the case then how long before a customer's energy usage pattern changes? Would customers revert back to previous habits over time? All of these questions are essential to consider when examining the continued use of demand response technologies and how they affect the persistence of energy savings.

Persistence of Peak Demand Energy Savings of Devices

In terms of the impact on peak demand among National Grid adopters of technology, in Figure 21 below it shows that in 2015 all of CPP technology levels saw a decline in energy usage over the course of the summer, however in 2016 peak demand reductions stayed fairly consistent across all CPP technology levels over the course of the summer (Navigant, 2017). Although these charts track the level of energy reduction for customers who acquired these technologies, they do not indicate whether or not customers who discontinued use of these technologies maintained similar levels of peak energy demand reduction to those who continue to use these technologies. Moving forward, National Grid should see if customers' discontinued use of technology has any effect on their energy consumption patterns.

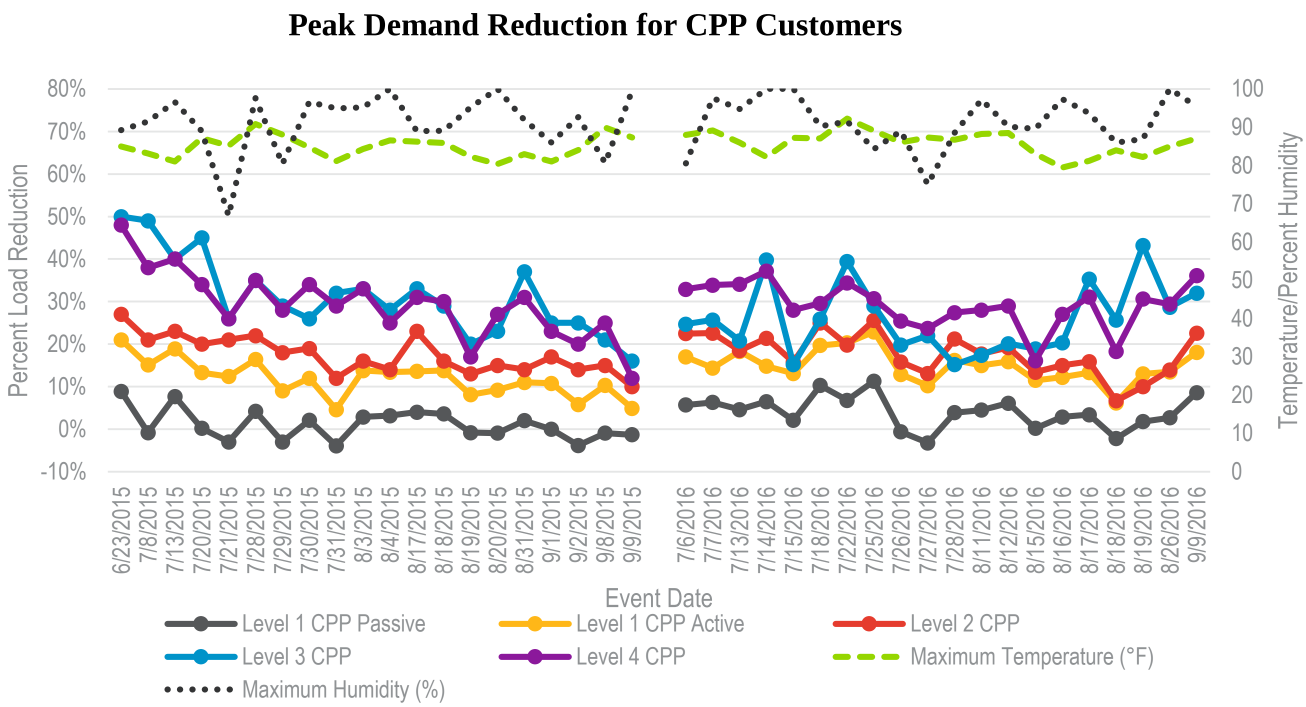


Figure 24 - Peak Demand Reduction for CPP Customers (Navigant, 2017)

Additional Psychological Barriers

There are several other possible psychological barriers to the adoption of demand response technologies that are beyond the scope of this report's analysis but which National Grid should be aware of moving forward. Trust is a significant barrier to utilities in all aspects of business. According to a 2013 global study by Accenture, "less than one-quarter of consumers trust their utility to inform them of actions they can take to optimize energy consumption" (Accenture , 2013). Customers may also have concerns regarding the privacy of data collection or the radiation that may be emitted from smart meters. These additional factors have not been covered within the scope of this report but are nevertheless potential barriers to adoption.

Summary

By utilizing the Hierarchy of Effects marketing framework to view the adoption of consumer-focused demand response technologies, National Grid and other utilities can gain a better understanding of the different steps in this process from awareness to preference to purchase and loyalty. The utility industry has traditionally been one where companies have not had to market their product (electricity) due to customers typically only having the option of one power provider. Therefore, incorporating this type of marketing analysis can help utilities better identify of areas of improvement for adoption of these technologies and more broadly acquire a better understanding of their consumer base's preferences. In the case of National Grid, moving forward areas for improvement include making customers aware of their products, gaining a better understanding of customers' perception of the usefulness and ease of use of these products, and also examining customers' persistence of energy savings.

Recommendations and Discussion

Recommendation 1) Determine Benefits and Costs of Technologies

Navigant's 2016 SES demand response impact results show that each of the CPP technology levels (Level 1 CPP – Level 4 CPP) are statistically significant, indicating that these different technologies have a verifiable impact on peak demand reductions. However, what is unknown is the relative benefits and costs for each of these technology levels. For example, although Level 2 CPP customers have achieved peak demand reductions of up to 18% in 2016, what are the monetary benefits for National Grid which can be attributed to IHDs and what are the costs associated with IHDs for installation, and maintenance? How much of the demand reduction can be attributed to the web portal or education efforts? This benefit-cost analysis should also include more broad impacts such as potential savings for future grid expansions. An analysis for each of the CPP technology levels[4] will provide National Grid with information on which technology levels are most cost effective in reducing peak demand and better evaluate where to focus their efforts for future expansion of the smart grid.

Next Steps

- *Conduct a benefit-cost analysis of each CPP Level.*

Recommendation 2) Analyze Energy Use of Customers who Discontinue Use of Technology

National Grid should analyze the energy usage of customers who have discontinued the use of technologies such as the web portal and IHD. If peak demand reductions of customers who discontinue use of these technologies are found to be the same as those who continue to use these technologies then National Grid can consider to what extent it needs to maintain and replace these technologies, particularly in the case of the IHD.

Next Steps

- *Run an analysis to see if there is a statistically significant difference in peak energy reduction by technology level between customers who have been utilizing their technologies for the entire pilot compared to customers who have discontinued use prior to June 1, 2016. A separate analysis should be run for each CPP Level 1 – 4.* (The June 1, 2016 date is chosen because this is prior to the start of the 2nd summer's conservation day period from June 1 – Sep. 30).

Running these analyses will allow National Grid to see whether customers who have utilized one more of these technologies but discontinued use, will stay consistent in their energy usage or revert back to previous usage habits.

[4] PTR levels should not be included in the benefit cost analysis because they make up less than 5% of SES customers and the peak demand reductions are not statistically significant.

Recommendation 3) Include the Environment and Society in Future Marketing

In both the case of National Grid and SMUD, survey results indicated that motivations to participate in the pilot programs included the environment and climate change. Moving forward, National Grid and other utilities should examine whether or not to include marketing messaging about benefits to the environment and society for smart grid programs and demand response technology.

Next Steps

- *Conduct market research to determine the effectiveness of including messages about the benefits to the environment and society provided by the smart grid and demand response technologies*.

Recommendation 4) Increase Focus on the Web Portal and Smart Phone App

In 2014, 27.5% of Worcester households did not have an internet subscription (U.S. Census Bureau, 2015). In addition, 19% of American adults have no broadband service available at home other than a smart phone data plan and/or they have limited options for online access other than a smart phone (Smith, 2015). IHDs, PCTs[5], and LCDs all require a connection to the internet through the home, but the web portal does not. The web portal is the only technology available to the nearly 1 in 5 American adults who have no access or limited access to the internet other than through their smart phones. Therefore, ensuring that National Grid's web portal is easily accessible is essential for National Grid's pilot program and for other utilities.

Next Steps:

- *Eliminate the 24 hour waiting period and simplify the sign up process for the web portal.* Currently, pilot participants who want to sign up and access the website first have to create a National Grid online account, wait 24 hours, and then they can create a separate Worcester Smart Portal account. This extra step in the sign up process decreases the Perceived Ease of Use of the technology.
- *Make signing up for technology as simple, easy and straight forward as possible.*

Recommendation 5) Increase Focus on PCTs, Target Customers with Central Air Conditioning

In New England, from 2011 – 2016 the percentage of households with central air conditioning increased by 3.2% annually and from 2015 – 2024 New England's summer peak demand is expected to increase by 0.6% annually. (U.S. Census, 2014; ISO-NE, 2016) In addition, the DOE's Final Report indicated that customers who were offered free PCTs had peak demand reductions that were substantially higher than those who were not offered free PCTs. (U.S. Department of Energy, 2016). National Grid's results in the interim and final Navigant

[5] Customers without internet can connect their PCTs to their smart meter but this also requires the use of a gateway device.

evaluation reports reflect the value of PCTs in reducing peak energy demand. Despite only 28% of homes in New England having central air conditioning, the addition of PCTs to these homes would substantially reduce peak demand and would also likely have a high benefit-cost ratio for utilities.

Next Steps:

- *For future expansion of the smart grid, target neighborhoods and areas with higher concentrations of central air conditioning.* [6]

If any of the technology levels are found to have benefit-cost ratios which are not optimal then National Grid can consider what changes can be made to improve the benefit-cost ratios or whether or not certain technology levels should be changed or altered.

Recommendation 6) Revaluate Survey Questions to incorporate TAM model

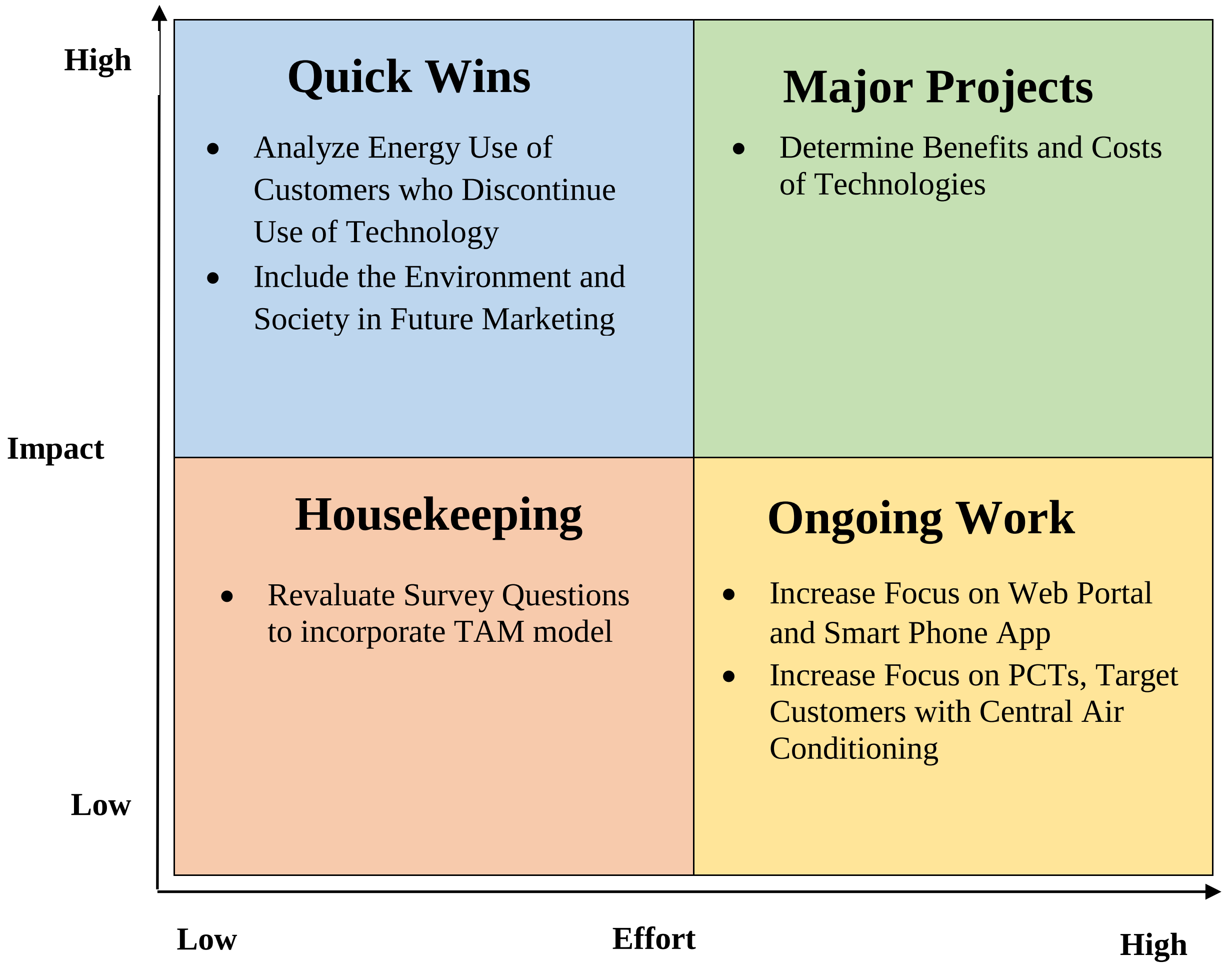
National Grid should consider revaluating survey questions to incorporate the Technology Acceptance Model framework to better understand customers' perceived usefulness and perceived ease of use of National Grid's technology offerings.

Next Steps:

- *Collaborate with Navigant to develop survey questions based on the TAM model that directly address structural and psychological barriers to demand respond technologies.*

[6] A key point to consider is that although PCTs have a substantial impact on reducing peak demand and likely have high benefit-cost ratios, trying to target customers with central air conditioning, while being effective in achieving peak demand reductions, may also lead to the targeting of high income customers, who are more likely to have central air conditioning. National Grid and other utilities should carefully consider this when considering whether or not to target customers with central air conditioning.

Priority Matrix for Recommendations



Conclusion

Consumer focused demand response technologies play a vital role in reducing peak demand. Benefits from the reduction of peak demand include: reduced stress on the grid, fewer power outages, cost and environmental savings for utilities and customers, and decreased need for future additions of costly infrastructure. Looking at National Grid's SES program and other smart grid pilot programs it is clear that there is a relationship between the adoption of some of these technologies and higher rates of peak demand reduction. Given the difficulties faced by National Grid and other utilities in encouraging the adoption of technologies, understanding what the barriers are to the adoption of these technologies and how they can be overcome is essential. Understanding these barriers is a crucial step for achieving the ultimate goal of these consumer-focused demand response technologies, which is to reduce peak energy demand and improve the efficiency of our power system by better balancing supply and demand of energy while also providing monetary and environmental savings to both utilities and customers.

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