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Consumer and Market Optimized Design of Residential DR Programs using Connected Devices: Insights from consumer research

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1 Executive Summary

Residential demand response (DR) programs relying on air conditioners, water heaters, and other larger electric loads have been around for decades [1] showing appealing payback times on the order of three years for large-scale deployments. Residential DR projects that take advantage of connected devices offer an array of mostly untapped opportunities to reduce peak demand. The Smart Home segment has been steadily growing over the past few years. This includes both large and small appliances provided they are connected to the internet. According to one source, the penetration of stand-alone and integrated Smart Homes is predicted to reach 13.6% in 2019 [2]. On the other hand, the rate of ownership of smart thermostats by broadband homes reached 13% in December 2017 [3]. The growing customer interest in connected devices, together with home energy storage and electric vehicle charging are all contributing factors for the forecasted opportunity of 88 gigawatts of residential demand flexibility in the United States by 2023 [4]. However, for demand response programs to be cost-effective, extensive customer participation is required. To achieve this potential and support the design of effective and inclusive demand response programs it is necessary to study the attitudes, the barriers and the incentives that promote customer enrollment.
In collaboration with National Grid, Fraunhofer CSE examined the attitudes and barriers for customer enrollment in demand response programs, studying, in particular, National Grid's ConnectedSolutions program, relying on WiFi (connected) thermostats. To that end, three focus groups and four usability tests were conducted. The focus groups and usability insights shaped National Grid's outreach strategy and helped to shape changes to the online portal designed to enroll customers into the program. The focus groups insights also informed the design of a field intervention that relied on community-based social marketing techniques to enroll customers into the program. Finally, a State-wide survey was conducted to evaluate the appeal of participation in demand response programs for the residents of Massachusetts. A summary of the main insights of this study is presented in the following paragraphs.

Program design

Override. The option to override and opt out of demand response events is a key latent factor that significantly explains customers' preference for voluntary instead of automated demand response programs. Even though voluntary demand response programs are not a novelty, automation awards utilities the opportunity to achieve more predictable peak demand reduction goals. Opt-out and override options should be a centerpiece of program design, and communication of these program aspects with the customers should be carefully designed and tested.

Comfort: For a small group of survey participants who are most averse to participation in demand response programs, losing comfort (together with locus of control) is a significant concern. Therefore, communication with the customers should also focus on maintaining comfort and the ease/convenience of participation.

User experience: Too often, programs, systems and applications are designed with a focus on business goals and technological capabilities but forget that they require massive customer engagement to be successful, largely ignoring the needs of the customer-user. Involving the user early on in the design process will help tailor the language used to convey complex ideas to different market segments. It will also help avoid functional and technical interface flaws that can frustrate users and keep them from enrolling or engaging with the software platform.

Other connected enabled appliances: Across age groups, dishwashers and washing machines, together with the more conventional WiFi (connected) thermostat, are natural candidates for demand response. The habit of showering at a particular time is the hardest to modify, but the impact of DR over the temperature of the water in the water heater is minimal. Therefore, all communication involving automating water heaters needs to be carefully designed to reduce customers' concerns about convenience and comfort and increase enrollment.

Incentives: Enrollment incentive and participation reward were the most popular option, closely followed by a monthly discount, which indicates that costumers favor constancy and certainty. Incentives for referral of friends or family, should also be included.

Customer testimonials and mass marketing. User feedback indicated that other customer testimonials about their experience with the DR program were a pivotal attribute to entice participation. Participant testimonials were going in parallel with advertising the program on mass media and taking advantage of economies of scale realized through other cross-marketing media. These include promotions on the website, bill inserts, TV, newspaper, and radio advertisements.

Wording of the marketing materials: The language used to disseminate information about the program should be relevant to the socio-cultural context of the target population and should focus first on the customers' benefits. It should also be related to the population beliefs and attitudes and, for example, focus on "savings" and "comfort."

Program delivery

The role of aggregators and vendors: Previous research [5] has found that customers who mistrust utilities are less willing to participate in direct-load control programs. In our study in Massachusetts, we concluded that the customers overall don't seem to openly distrust utilities. But we also found that the customers are more open to accept direct control over their connected devices if that control is performed by those vendors instead of the utility. Therefore, collaboration between utilities and connected device companies would likely increase engagement and participation of customers.

Community-based marketing: By relying on existing communication channels and socio-cultural referents, community-based outreach techniques can make abstract concepts relatable to customers and build trust. The small experiment conducted in the scope of this study showed that community based social marketing are productive in increasing customer awareness and incentivizing enrollment. The campaign was based on low-cost measures and techniques that can be easily implemented to maximize enrollment.

2 Introduction

Demand response has the potential to be a cost-effective tool to help Massachusetts delay expensive investments in generation, transmission and distribution otherwise necessary to meet a small number of peak hours a year. It can also potentially alleviate local constraints or be activated to increase grid reliability during emergencies to avoid blackouts or brownouts.

The definition of a demand resource is comprehensive: A "demand resource" is a dispatchable or non-dispatchable capacity product, a type of equipment, system, service, practice, or strategy" [8]. Customers with dispatchable demand resources enter into contracts with utilities or demand-response aggregators for demand reductions and may face penalties for non-performance. Those resources are typically activated by the utility, although customers can, in some cases, opt out. Non-dispatchable resource customers can participate independently in price and time-based demand response, with real-time pricing, critical peak pricing, peak time rebates and time of use tariff schemes. Traditionally, non-dispatchable resources are activated by the customer who voluntarily adjusts their consumption during periods of high electricity prices [8]. Both dispatchable and non-dispatchable resources can rely on connected devices that can be remotely programmed and activated to respond to DR requests. As such, residential demand response relying on connected appliances like air conditioners, water heaters, and other larger electric loads has been around for decades [9]. These devices confer another level of flexibility and control to residential assets by allowing customer participation in dispatchable and non-dispatchable programs (see Figure 1).

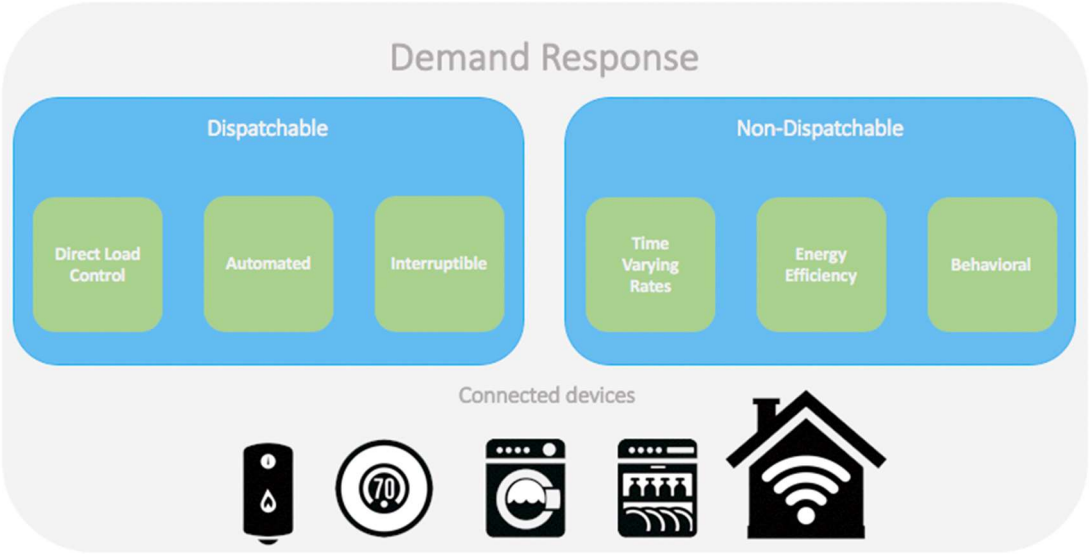

Figure 1: Dispatchable and non-dispatchable demand response can be facilitated by connected devices (left to right: connected water heater, connected programmable thermostat, connected washing machine, connected dishwasher, connected home).

DR relying on connected appliances like air conditioners, water heaters, and other larger electric loads has been around for decades [9-11]. It can be voluntarily activated by the customer or automatically activated by the utility. But to be cost-effective and have a measurable impact, these programs require significant penetration of connected appliances, widespread enrollment and active participation of

residential customers, due to market fragmentation and limited ability to significantly reduce consumption by each individual appliance.

With the increased adoption of residential connected devices, the opportunities for demand response continue to grow. Automated meter infrastructure (AMI) is an enabler of the regulatory changes required to allow the implementation of flexible tariff schemes that create an incentive for participation in demand response programs. Approximately 70 percent of the U.S. customers surveyed are aware of AMI [10], of which two-thirds are interested in receiving energy use information that is enabled by advanced interval meter readings. Nationwide, about 72 million advanced meters deployed nationwide in 2016 out of a total of 151.3 million (47.6 percent penetration rate [11]).

Recently, the Massachusetts DPU partially rejected the grid modernization plans of Eversource, National Grid and Unitil, stating that existing meters can still provide interval data, although recognizing that two-way communication needs to be implemented [12]. The Massachusetts DPU is also unsure of the business case for advanced metering as time-based rates are not broadly adopted by customers [12]. Coincidently, in the ISO-NE region, demand response participation has decreased by 19MW from 2016 to 2017 [11], due to lower than expected enrollment in the real-time demand response program in Western, Central and Northeast Massachusetts [11]. But this trend could evolve according to a study by SECC [10], as 75 percent of the segment of customers particularly engaged with AMI, report being either “probably interested” or “definitely interested” in participating in programs that reward them for reducing electricity use at peak times, such as peak time rebates [10], with millennials seeming to be particularly favorable to DR participation.

2.1 Purpose

The purpose of this report is to develop customer insights about how residential DR programs using connected devices are perceived in the Commonwealth of Massachusetts and to propose recommendations to improve program design to improve customer enrollment and participation in Massachusetts. Specific objectives are to:

a) Develop a deep understanding of the barriers to customer acceptance of residential demand response programs and the deployment of related enabling technologies;
b) Design a residential DR program to directly address these barriers;
c) Demonstrate the peak savings potential of automatic residential DR;
d) Develop a framework of best practices to promote future programs in the Commonwealth, and
e) Achieve between 30 to 40 percent enrollment rate of the eligible target population.

3 Residential demand response programs in the Unites States

Residential demand response programs relying on connected devices have been maturing with time. Participation in demand response is largely supported by the widespread penetration of advanced interval metering infrastructure (AMI) that allows for the design of more flexible tariffs that provide incentives for residential customers to manage their electric demand according to system constraints. AMI is also useful for evaluation purposes and for providing feedback to customers about their electricity use. During 2017-2018, electric utilities in Florida, Mississippi, Rhode Island and Virginia received approval for large-scale deployment of advanced meters in some case as part of grid modernization efforts. According to FERC's Demand response and advanced metering analysis report [11], regulators in several states including Maryland, Minnesota, Ohio and Pennsylvania have recently approved, or are considering, time-based rate pilots some in combination with proposed electric vehicle charging infrastructure investments. In other states, including California and Pennsylvania regulators are considering next steps for demand response and time-based rate programs. In Massachusetts and Kentucky, state regulators and utilities are taking more targeted or cautions approaches to advanced meter deployment.
Alternatives for DR without an AMI infrastructure in place exist, mostly enabled by the increased penetration of connected programmable thermostats and, potentially, other connected appliances. In other states, such as Texas, regulators are seeking to get more benefits out of their existing advanced meters by leveraging those investments through for example data sharing mechanisms [11]. To provide a feel for the range of DR programs and initiatives in the United States, this section gives examples of residential DR programs and pilots using connected technology to enable demand response[1]. These examples are organized according to their main focus: time-based rates shaping every-day demand; peak day events to mitigate seasonal variability, and emergency response to increase system reliability.

3.1 Time-based rate programs

Time-based rate programs take advantage of an AMI infrastructure that can record electricity usage on a frequent basis. Interval data enable customers to be introduced to new types of pricing programs that better reflect the cost to provide electricity at different times of day. These programs include time of use pricing (TOU), and dynamic pricing: real-time pricing (RTP), variable peak pricing (VPP), critical peak pricing (CPP), and critical peak rebates (CPR). Combined with connected technology, TOU programs are designed to shape domestic demand by penalizing electricity use at times when electricity cost is high. FERC [11] considers the slow implementation of time-based rate programs to be the principal barrier to greater customer participation in demand response, although, overall, customer participation in those programs has increased (approximately five percent in 2016). From a different perspective, the Massachusetts DPU regards customer adoption of time-based rates as ineffective and intends to study the barriers keeping customers from enrolling in time-based rates. The case studies described in Tables 1 and 2 illustrate programs designed to shape residential demand response, employing a combination of connected technology, and time of use rates. These case-studies represent concepts that rely on multiple connected devices: programmable thermostats, connected refrigerators, water heaters, washing machines, and dryers. Results indicate that the customer might not be interested in paying the higher

[1] Overall, demand resource participation in wholesale markets increased approximately three percent from 2016 to 2017 to a total of 27,541 MW. The contribution of demand resources to meeting peak demand rose to 5.6 percent in 2017 from 5.3 percent in 2016 [11].

market price of connected appliances, but alternatives exist. These include connected switches and other connected enabling devices, with a lower price point.

Table 1: Hawaii Electric: TOU as part of the program design to increase grid reliability

Hawaiian Electric, Hawaii' Electric Light, Maui Electric Rewarding customers for sharing control of energy use [13]	
Description of the program	The widespread integration of distributed renewable resources in Hawaii put the electric grid in stress. Demand response is seen as a means to increase local grid resilience and to control costs. Customer participation is a fundamental requirement, and local utilities and the local Public Utilities Commission (PUC) have been piloting novel regulatory tools to increase customer enrollment and active participation. The PUC has approved a comprehensive new portfolio of programs that will reward customers of the Hawaiian Electric Companies who can use their own equipment to participate in the management of the electricity grid. Third-party aggregators will enroll customers, aggregate and optimize demand capabilities and make it available to utility grid operators. The companies are in the process of developing tariffs, rate schedules and grid service purchase agreements with the aim of having the first participants online by the second half of 2018
Program Delivery	Third-party aggregators
Mode of DR	Automated demand response
Incentives	Bill credit to support the installation of wireless switches. Dynamic rates and purchase agreements
Target market	Residential and businesses
Connected Device	Smart switches, HVAC, outdoor lighting, signage and window displays, Fountains, saunas.
Impact	In implementation

Table 2: Detroit Edison Electric Smart Currents Project

Smart Currents Project Detroit Edison Company (DTE)[14]	
Description of the program	System-wide roll out of 449,000 AMI meters and installation and distribution of automation equipment. The residential program focuses on determining customer response to interventions combining In-Home displays, communicating thermostats and time-based tariffs (a three-period TOU rate with a CPP overlay during the peak period (weekdays and non-holidays 3 – 7 p.m.)). Critical peak events were announced with day-ahead notice to participating customers. Up to 20 critical peak events could be called each year. Control and information technology treatments included the deployment of IHDs and programable thermostats. In addition, all customers participating in the study received web portal access, customer support, and a variety of education materials. A subset of these customers also received smart appliances: Smart Kitchen (Refrigerator and Dishwasher), Smart Laundry (Front loading washer and dryer) and Smart Suite (Kitchen plus Laundry set).
Program Delivery	DTE Electric
Mode of DR	Programmable thermostats, In-Home Display and Time of Use and Critical peak pricing Rates
Incentives	Dynamic rates: time of use throughout the year and critical peak pricing for emergency days.
Target market	Residential
Connected Device	AMI, web platform, communicating thermostat, dishwashers, dryers and refrigerators

Impact	5,400 Homes. The recruitment effort fell short of its goals (6000) and so several of the experimental cells had to be dropped or consolidated to maintain, to the degree possible, statistical power in the resulting load impact estimates. Recruitment for smart connected appliances proved challenging for reasons of home layout and inadequate fuel source (gas instead of electricity for some appliances). Customers weren't willing to be taxed for the wholesale cost of the appliances. Generally, customers accepted the increase in cost of the delivery charge ($200). Interestingly, the evaluators noted that despite the limited number of participants, it seemed that those engaged with the connected appliances were less willing to pursue other ways to reduce energy costs. Based on the results, DTE is offering the TOU with CPP rate designed for the study to its entire residential population on a voluntary basis.

3.2 Peak day event programs

Utilities in several parts of the country have implemented peak day event programs. The case studies described in this section reflect the range of design characteristics of peak day event programs.

Table 3: Summer Discount Plan, SCE

Summer Discount Plan (SDP), Southern California Edison [15]	
Description of the program	The utility cycles customers' air conditioning units directly, depending on enrollment options. Customers receive notifications about when a summer discount plan event is scheduled, when the event starts, and when it ends via their smart phone. Customers who have enrolled in SCE's SmartConnect enabled program (AMI) are also offered dynamic tariffs, such as peak-time rebates. The program was converted to a price-based program where events will be implemented more frequently than what had been the case historically, for reliability purposes.
Program Delivery	Southern California Edison.
Mode of DR	Utility control over air conditioning units
Incentives	The SDP for residential and commercial customers offers two primary options for participation and provides credits for customers with amounts that vary by option. The two options refer to the choice of cycling strategy and to limits on the number of hours or days that events may be called. Residential and commercial customers may choose a 100 percent or 50 percent cycling strategy (commercial customers may also select a 30 percent strategy). Customers receive bill credits (up to $180 /year) for participation.
Target market	Residential and Commercial
Connected Device	Direct load control of residential and commercial air conditioning units
Impact	SDP is an air conditioner (AC) cycling program with over 310,000 residential and 10,000 commercial customers enrolled. 100% cycling: 25% - 27% load impact 0.21 kW/AC air ton; 67% cycling: 19% load impact 0.17 kW/AC air ton; 50% cycling: 10% - 15% load impact 0.08 kW/AC air ton.
Lessons Learned	The load reduction for the peak events is followed by small increases over the next several hours [15].

Table 4: Save Power Day Nest/Energy Hub Pilot, SCE

Save Power Day Incentive Plus Nest/Energy Hub Pilot, Southern California Edison, Summer 2013[16]	
Description of the program	Goal of the program was to use smart thermostats to optimize energy efficiency and DR with customers' HVAC systems. A bring-your-own-thermostat (BYOT) program, Save Power Day Incentive Plus, offers customers a $100 rebate for the purchase and installation of a smart thermostat, along with a $25 added incentive for enrolling in the DR program. SCE precools the customer's home, then sets up the thermostat 2 to 4 degrees during the DR event. If it gets too uncomfortable for the customer, the customer

	can override the event by turning down their thermostat. Events last up to four hours between 11 a.m. and 8 p.m. on non-holiday weekdays. In 2018, customers can bring multiple thermostat vendors and aggregators to the program: EnergyHub, Nest Labs, Simple, Venstar, Whisker Labs, and Zen Ecosystems.
Program Delivery	Utilities initiate a DR event, vendors deliver the program
Mode of DR	Connected Programmable Thermostats
Incentives	$125 annual bill credit
Target market	Residential and Commercial
Connected Device	Air conditioning units
Impact	In 2013, 3,000 customers; average load reduction per household was 0.70 kW. In 2018 program enrolled 43,000 customers.
Lessons Learned	Program designed around the customer: comfort (pre-cooling and override), choice (multiple thermostat vendors), and cost (low enrollment cost and high incentive ($125 bill credit in 2018).

Table 5: Smart Thermostat Pilot, Excel Energy Colorado

Smart Thermostat Pilot, Excel Energy Colorado, 2015 [17]	
Description of the program	Residential electric and natural gas Xcel Energy customers are eligible to receive a rebate for purchasing and installing a qualifying smart thermostat. In addition to the rebate for purchase and installation, another subset of customers that are electric customers of Xcel Energy can receive rebates for participating in demand response
Program Delivery	Storefront purchase and mail-in rebate channels.
Mode of DR	Demand response events are executed via smart thermostats through a utility-controlled demand response portal provided by a participating thermostat manufacturer.
Incentives	$50 rebate, eligible for purchases and installation of smart thermostats between Jan 2015 and Dec 2016
Target market	Residential and small businesses
Connected Device	Xcel Energy's pilots were designed to test a variety of program models and thermostat manufacturers. The pilots have also provided a strong empirical basis for answering several important research questions and informing the Company's smart thermostat strategy going forward. Five vendors: nest, ecobee and Honeywell, Radio thermostat of America and EnergyHub.
Impact	6,300 devices; The annual energy savings analysis was performed using pre- and post-treatment billing data, which could not be estimated for HVAC specific savings because end-use specific data was not available for the pre- and post-treatment period. In contrast, estimated peak load impacts due to energy savings could not be directly estimated because this would require hourly interval data and no smart meter interval data were available. In the absence of interval data, peak load impacts for summer afternoons were estimated by applying results from a similar smart thermostat study that evaluated impacts by summer weekday hour using interval data. By applying the assumption that savings were similarly allocated for Xcel Energy participants, the estimated average peak impact is about 0.25kW from1 to 5pm.
Lessons Learned	80% of respondents reported that the $50 rebate was very or extremely important, implying that the rebate was compelling. Further studies may be necessary to develop a reliable savings estimate or deemed savings value.

3.3 Emergency response

In response to high temperatures in the summer, grid operators and utilities issue emergency requests for emergency demand response, critical peak pricing, and voluntary conservation. Recent examples of emergency demand response occurred in the NYISO region due to a heat wave in the State. In 2018, the

NYISO activated an estimated 495 MW of emergency demand response for several hours due to the unexpected outage of a 345kV transmission line in the city. On September 3, 2018, in ISO-NE a voluntary emergency response by market participants was also reported. Although these programs typically target commercial and industrial facilities examples with residential also exist. With the increased adoption of connected devices and the deployment of an AMI infrastructure, residential customers could also become active participants of emergency DR in response to increased grid volatility.

Table 6: Hawaii's Electric Energy Scout

Hawaii's Electric Energy Scout [18]	
Description of the program	In 2008, Hawaii's electric installed remotely controlled switches on in-home electric water heaters and cooling systems to temporarily turn off the heaters and cycle the cooling systems during peak demand periods and generation emergencies. It also allowed HECO to obtain more control over electricity use among its residential customers, which puts the utility in a better position to supply power across the island without interruption.
Program Delivery	Third-party aggregators
Mode of DR	Automated demand response
Incentives	Bill monthly credit ($3 for water heaters or $5 for air conditioners)
Target market	Residential and businesses
Connected device	Wireless switches for air conditioning units and electric water heaters
Impact	The pilot reached its goal, curtailing 27 MW by the end of 2009. Hawaiian Electric continued with their Energy Scout program, offering customers a bill credit Over 34,000 customers participate in the water heater program, while 4,000 customers participate in the air conditioner program, collectively representing 17.5 MW of controllable peak demand
Lessons Learned	The program proved effective to help control grid volatility in a service area characterized by a broad integration of distributed renewable resources and electric vehicles, and it continues in effect.

3.4 Discussion

With the increased adoption of connected devices and automated metering infrastructure, residential demand response has the potential to expand. AMI enables the design and introduction of new pricing schemes that reflect the real cost of producing electricity during the day, while automated control of connected technologies, either voluntarily enabled by the customer or automatically enabled by the utility helps shape everyday load profiles. Connected technologies promote participation in peak-day events designed to mitigate seasonal peaks and emergencies. Over time, several types of connected devices have been the target of residential DR programs, foremost AC and electric water heaters. Due to their independence from an AMI infrastructure, communicating thermostats give utilities the opportunity to offer residential DR where an AMI infrastructure does not exist. In such cases, savings and active participation are directly calculated from the thermostat's interval data, which partially explains the popularity of such programs.

Other pilots, primarily supported by an AMI infrastructure and flexible tariffs, target larger connected appliances, such as the connected refrigerator, dishwasher, dryer or washing machine. However, high upfront costs and uncertain pay-back times limit the appeal of those appliances for the residential customer. This effect may change with time, as connectivity becomes a feature in a greater range of appliances and with the introduction of more flexible and creative business propositions in the

residential market (shared costs, rebates, flexible tariffs, and higher volatility of the electrical system). Smart switches and other enabling technology are an intermediate alternative to include water heaters and air conditioning systems in residential DR programs. The case studies discussed also show that customers are willing to accept a range of incentive schemes, including bill credits, enrollment and participation incentives and time of use or other dynamic rates.

4 General attitudes and barriers towards enrollment in programmable connected thermostat DR programs

This section focuses on gathering insights regarding the general attitudes and barriers of Massachusetts residents regarding participation in programmable connected thermostat DR program in Massachusetts. To do this study Fraunhofer USA, CSE collaborated with National Grid. The case study was the 2016 ConnectedSolutions Program, and the user study, comprehending three focus groups and four usability tests was conducted in the Spring of 2017.

4.1 The case study: increasing enrollment rate in National Grid's residential DR program

Launched in 2016, National Grid's ConnectedSolutions program provides customers with the ability to connect Wi-Fi enabled devices in their home to a platform that will automatically manage their electricity use to reduce peak demand. The ConnectedSolutions program was unable to enroll the same number of customers as Nest's parallel RushHourRewards program (Figure 2). In 2016, the first year of the program, customers could enroll Honeywell and ecobee connected thermostats (CTs) in the National Grid portal.

By the end of 2016, approximately 2,300 CTs enrolled in National Grid's Demand Response program in Massachusetts, of which 22% were through the bring your own thermostat (BYOT) program, and about 5% were direct install [19]. In collaboration with National grid, Fraunhofer's team focused on understanding what could be the issues preventing customers from enrolling in the utility led program.

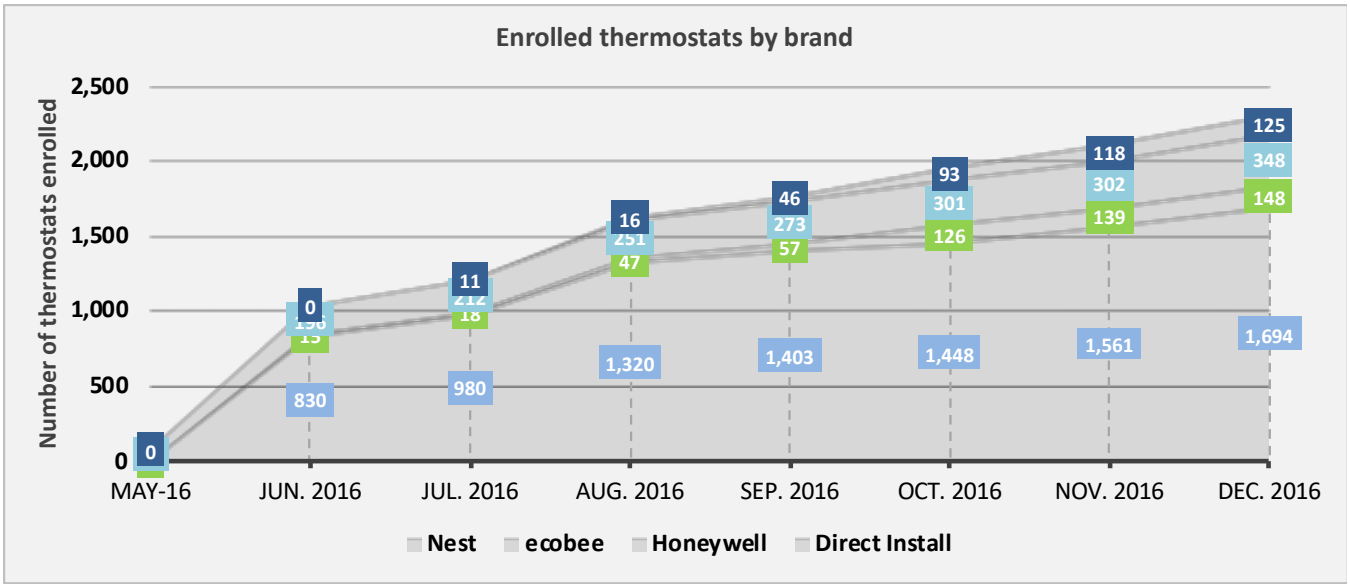

Figure 2: Number of thermostats enrolled by brand between May and December 2016

4.1.1 The Connected Solutions program

In 2016, on days of peak demand, customers were notified that an event would take place. During an "event" the thermostat temperature setpoint is increased by 2ºF for 4 hours. Home precooling preceded an "event." The benefits to the customer of participating in the DR Program are monetary: at the time of this

study, each customer receives ($25) for enrollment and ($25) for authorizing remote control of their thermostats, at least 75% of the times an event is called [20].

Three focus groups[2] [21] were designed to respond to the following research questions: What are the participant's attitudes and concerns about participating in demand response events? What are the main concerns regarding the utility outreach strategies? Which improvements could be made to help enroll others in the Program? Four usability tests were also conducted to determine if there were issues with the web platform that affected customer enrollment, as customers were required to use that platform to connect their thermostats [21].

4.2 Focus group insights

Obtaining specific insights into the different aspects of this program helps determine the themes related to the process of enrolling and participating in the program. Topics that stood out the most from the focus groups include comfort, flexibility, trust, and control.

4.2.1 Attitudes and concerns about participation in DR events

Participants report being comfortable with using the Internet across age groups and social classes, even people who self-identify as uncomfortable with technology. Therefore, this shouldn't be a barrier to customer enrollment in DR. When facing the prospect of increasing thermostat setpoints on hot days, participants worried about humidity and comfort. More general concerns were lack of confidence about customer long term savings and hidden costs. Concerns with the utility controlling the connected thermostat were also raised. Some participants suggested that their lack of control would have a significant negative influence on their comfort and trust for the program overall. Only a few participants were willing to cede control for the sake of the incentive and environmental concerns.

4.2.2 Main concerns about the utility outreach strategies

Thermostat vendors, with a well-established reputation, were perceived with having the welfare of the customer in mind, in stark contrast to utility companies. The majority of the focus group participants declare that they would delete any email received from a utility company, except for utility bills if the customer has signed up for e-bills. For these reasons, participants were more open to receiving e-mail messages from thermostat vendors inviting them to enroll their thermostats in the DR program.

4.2.3 From the perspective of the customer: what should be done to increase customer enrollment?

Participants considered the ability to override the events if necessary a key aspect of program design, while testimonials were deemed to be vital to improve customer awareness of the program and promote dissemination. Dissemination on mass media was also suggested, as a mainstream strategy.

[2] Recruited from craigslist (https://boston.craigslist.org/etc)

4.3 Usability experience

Figure 3: Usability test setting.

1. Usability test participant; 2. Facilitator; 3. Observer; 4. Video recorder; 5 Thermostat hanging on the wall. Picture taken from behind the lab's one-way mirror

The ConnectedSolutions platform was user tested by four users. Users were asked to follow all the tasks necessary to connect an ecobee thermostat to the platform [26]. The session was video recorded from an adjoining observation room through a one-way mirror (Figure 3). Issues of technical and functional usability, clarity and trust were found during the user testing process. A summary of the main findings is discussed in the following paragraphs. Technical usability Technical issues prevented users from successfully moving forward in the online platform[3] and were required to complete the same forms multiple times, from the beginning. During that process, the platform didn't validate the user in their choices or provide any support, causing frustration. As a consequence, users claimed that if they were at home, they would likely give up on trying to enroll in the program because the process was too frustrating, and the reward was not attractive enough.

4.3.1 Functional issues

Functional issues prevented the users from finding support when they were unable to proceed in the interface because there was no feedback during the creation of multiple profiles and user accounts necessary to enroll each thermostat, and there were no means of contact for troubleshooting any issues found. Multiple brandings of the portal made navigation confusing.

4.3.2 Clarity

The homepage of the ConnectedSolutions website used language that was too technical to be easily understood by the participants, which made the goals, benefits, and objectives of the program not fully clear. Users also claimed not understanding what was required for their productive participation.

4.4 Impact

A detailed report was presented to National Grid, resulting on the overall simplification of the portal in the beginning of August of 2017. These contributions together with the focus group feedback and additional changes demanded by National Grid marketing team resulted on a 168 percent increase in connected thermostats enrollment in the "ConnectedSolutions" program by the end of the season [21].

[3] The tests were conducted in May 2017 on the online platform in use at that time.

5 Generalizing the findings: State-wide survey

A Statewide survey was designed and deployed in October 2018 with the purpose of understanding the needs, attitudes and the degree of engagement of several customer segments in multiple variations of demand response programs. The study was designed to address the customer's sentiment towards voluntary or automatic control of large household electric equipment of large household electric equipment. Participant compensation, an essential component of program design, was also addressed in the survey. The main insights of the study will be presented and discussed in the next sections.

5.1 Socio-demographic characteristics

With a valid response rate of 43 percent, 985 responses were collected. The survey was balanced for gender (female= 52 percent and male = 49 percent), and age quota (Figure 4). 90 percent of the responses were obtained in counties that are in their majority urban, according to the Rural Access Commission of Massachusetts[4] because those counties account for a large majority of Massachusetts' population (Figure 5).

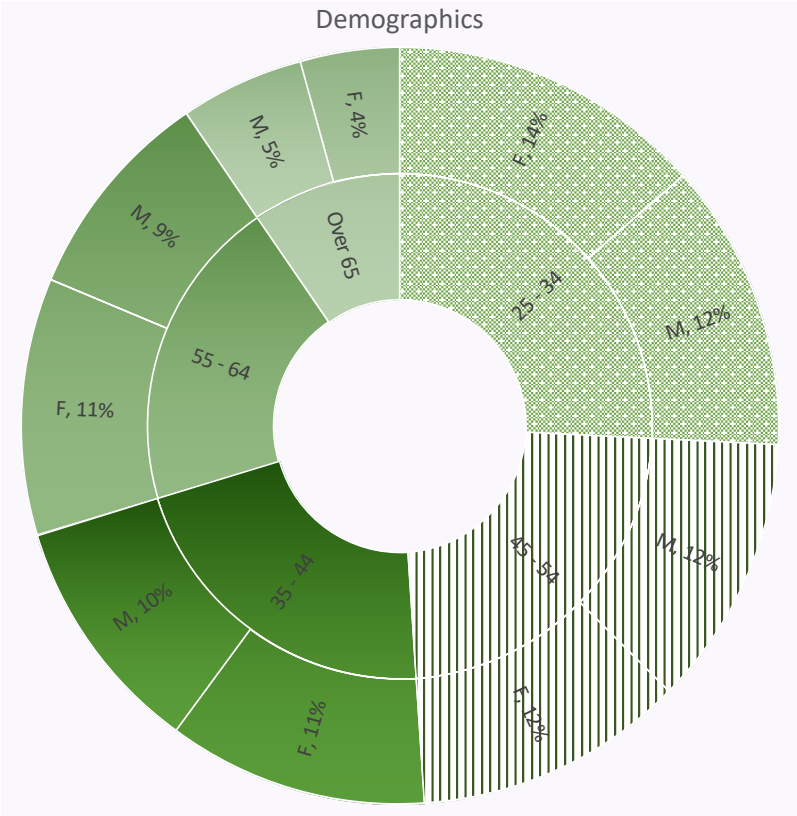

Figure 4: Gender and age distribution

[4] Commonwealth of Massachusetts, 2013. Special Commission on Rural Access and Improving State-Sponsored Services in Massachusetts Rural Communities. The Internet: https://www.mass.gov/files/documents/2017/10/02/rural-services-commission-report.pdf

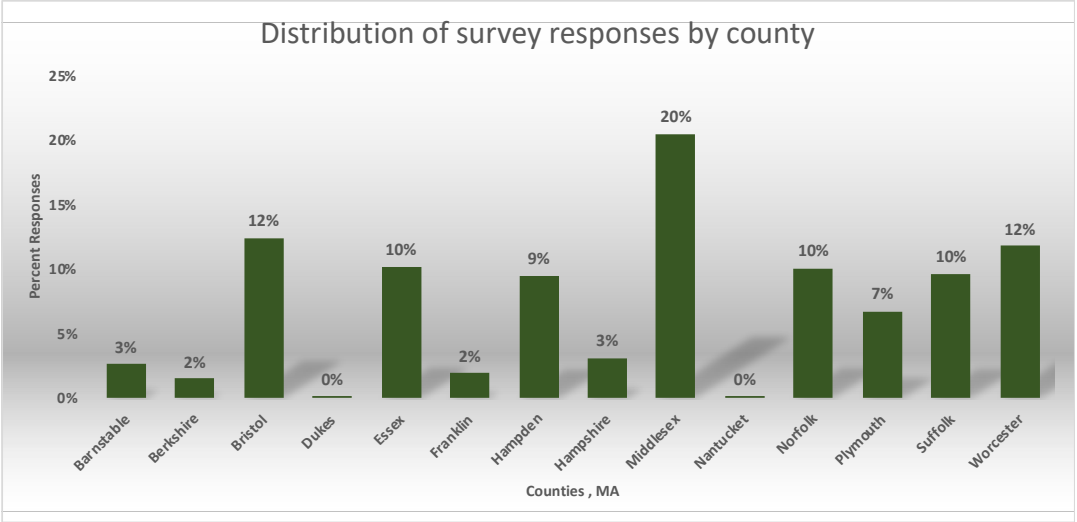

Figure 5: Geographic distribution of survey participants

5.1.1 Income

71 percent of the survey participant's yearly household income is below $100,000.00, of which 8 percent are classified as low income according to the 2018 Federal Poverty Guidelines[5], which co-references household size with annual household income (Figure 6).

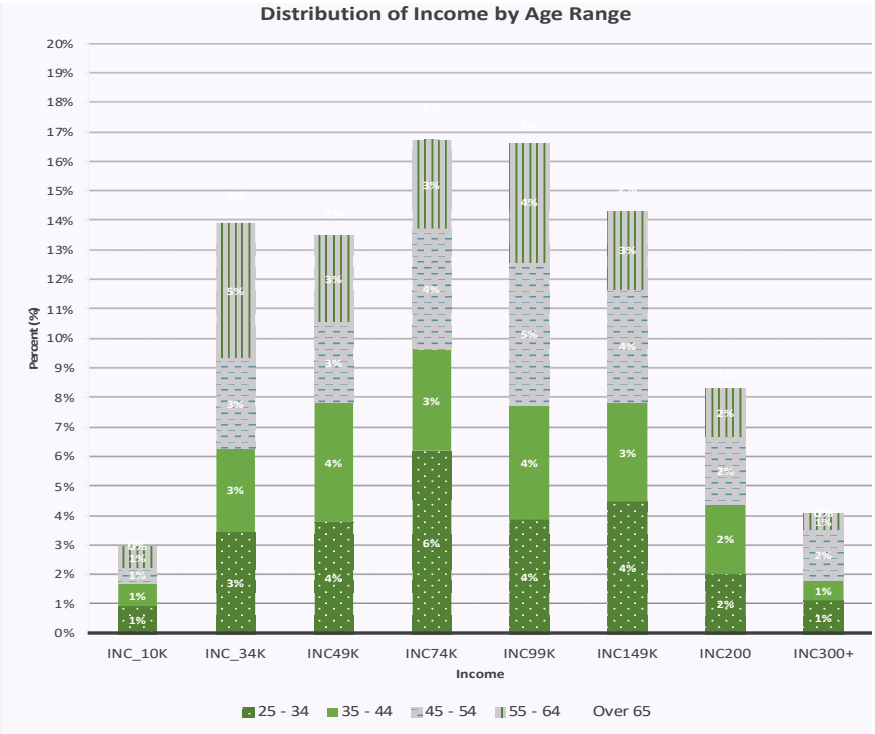

Figure 6: Distribution of income by age range

[5] 2018 Federal Poverty Guidelines. https://www.masslegalservices.org/content/federal-poverty-guidelines-2018

5.2 Preferences towards automated or voluntary control

Previous insights show that aspects related to individual control of household appliances during demand response events have a detrimental effect on customer participation in DR programs. To test this hypothesis, the survey asked respondents to choose one among three thermostat-based demand response programs. The following hypothetical scenario introduced the three programmatic options: "Suppose that you have a smart thermostat to regulate the temperature in your home. For hot summer days only, which program would you prefer?". Differences among programs were the mode of participation in DR (automatic or voluntary), the level of incentive ($50 or $30) and the duration of the event (four or six Hours). Participants were not offered the option to not participate (Table 7).

Table 7: Program design: voluntary versus automatic control

Program Options	Program description	Mode of participation	Incentive	Duration	Comments
Program A	Your electric company will automatically increase the thermostat by 2°F for 4 hours. You will be receiving $50 per year for participating.	Automatic	High Incentive ($50)	Short Duration (4 Hours)	Customers were offered the highest compensation for the shortest event duration if they choose an option that lets the utility automatically change the settings of the thermostat.
Program B	You are asked to increase the temperature of your house by adjusting the temperature of the thermostat by 2°F for 6 hours. You will be receiving $50 per year for participating.	Voluntary	High Incentive ($50)	Long Duration (6 Hours)	Like program A, customers are offered a higher incentive. Only, in this case, they would be in control of their thermostat settings. As a penalty, voluntary control for higher pay would require the customers to keep their changed thermostat settings for a more extended period (6 Hours).
Program C	You are asked to increase the temperature of your house by adjusting the thermostat by 2°F for 4 hours. You will be receiving $30 per year for participating.	Voluntary	Low Incentive ($30)	Short Duration (4 Hours)	This program was tailored for participants more uncomfortable with utility control. The participants who chose Program C did so for the same duration designed in Program A, but for lower pay. We call this group the DR "antagonists."

5.2.1 Results: voluntary versus automated control

Programs offering participants the option to voluntarily control their household appliances received the larger number of favorable responses (68 percent[6]; Table 8).

Table 8: Distribution of responses by DR program

Programs	N	%
PROG.A_DLC_4H_HI	314	32%
PROG.B_VC_6H_HI	436	44%
PROG.C_VC_4H_LI	235	24%

Younger segments tend to be more favorable toward automated control (Table 9).

[6] Binomial test indicates that the difference is statistically significant with $p<0.05$

Table 9: Effect of age in choosing an automated control program

Classes: Age Groups		Chose voluntary control (N=671)	Chose direct control (N=314)	% Difference
Between 24 and 34	N	149	105	
	% Dif.within class	58.7%	41.3%	17%
Between 35 and 44	N	139	72	
	Within class	65.9%	34.1%	32%
Between 45 and 54	N	166	62	
	Within class	72.8%	27.2%	46%
Between 55 and 80	N	217	75	
	Within class	74.3%	25.7%	49%

5.3 Program choices: in-depth analysis of participant segments

To obtain a profile of the segment who chose each program, we looked at the combined effect of multiple variables over the decision to select each program, using a structural equation modeling approach (Smart-PLS). The model hypothesized that environmental attitudes and individual beliefs could have a positive or a detrimental effect on the intention to participate in the demand response event. Other "latent variables" were age, household routines (measured by dishwashing and laundry habits and occupants during the day and utility bills. Social norms, measured by how much "others" or "family members" approve the decision and the locus of control, measured by the importance of overriding the DR are other dimensions that were incorporated in the model. Trust in the utility company, was subjectively included (Table 10). The graphical layout of the model, showing how the latent constructs were formed and their expected influence over intentions to participate in DR programs, is introduced in **Error! Reference source not found.**. Each model was trimmed to ensure internal reliability[7].

Table 10: Variables included in the segmentation models

Latent variables	Indicators	Survey question	Response range
Age	DEMO-A	Which category below includes your age?	25-34; 35-44; 45-54; 55-64; 65-80
Beliefs	T_CMFT	What first comes to mind when you think about increasing the temperature of your thermostat by 2-3F, during the summer?	Comfort
	T_BILL		Utility bill
	T_HYG		Personal hygiene
	T_ROUT		Routine
	T_HEALTH		Health
	T_FAMM		Other family members
	T_ENV		Protecting the environment
Bills	BILL	How much do you typically pay for electricity in July or August? If you cannot remember, please check your bill or provide your best estimate.	Less than $50; Between $50 and $75; Between $75 and $130; Between $130 and $170; over 170

[7] All indicators in the trimmed model showed reasonable factor loadings of at least 0.5 ($p<0.05$) and acceptable convergent validity (AVE> 0.5).

Latent variables	Indicators	Survey question	Response range
Environmental Attitudes	ENVR_CNC	Say how much you agree with the following: I am concerned about the environmental impact of human activities	Strongly Agree - Strongly Disagree Likert scale 7 points
	ENVR-P	I believe the environment needs to be protected	Strongly Agree - Strongly Disagree Likert scale 7 points
Intentions	THRM_WANT	...how much do you agree with the following? If I wanted to, I could raise the temperature of my thermostat by 2-3 °F , for 3 hours	Strongly Agree - Strongly Disagree Likert scale 7 points
	THRM_EASY	Raising the temperature of my thermostat by 2-3 °F , for 3 hours, would be easy for me to do	Strongly Agree - Strongly Disagree Likert scale 7 points
	THRM_LIKE	I would like to increase the temperature of my thermostat by 2-3 °F , for 3 hours	Strongly Agree - Strongly Disagree Likert scale 7 points
Norms	THRM_APPRV	My family / other household occupants would approve of me increasing the temperature of the thermostat by 2-3 F, for 3 hours	Strongly Agree - Strongly Disagree Likert scale 7 points
	DRPRG_THM_DLC_OTHERS	How much do you think other customers would approve of that program?	Very Likely - Very Unlikely Likert scale 7 point s
	DRPRG_THM_DLC_FAM	How likely is it that your family would approve of your participation in this program? - Very likely	Very Likely - Very Unlikely Likert scale 7 point s
Intrinsic characteristics (Habits of the family)	HSUMM_DAY	Please choose all that apply: On a typical weekday, there is usually someone home in the following periods of the day...	Home during the day or not home during the day (Boolean 1 - 0)
	ELECTHEAT	Does your home mainly use electricity (not gas or others) for space heating?	Boolean (1 - 0)
	AC	Do you use air conditioning to cool your home?	Boolean (1 - 0)
	DISH_WEEK	In a typical week in my home the dishwasher is run..	Multiple times during the day or at least one time during the day (Boolean 1 - 0)
	WASH_WEEK	In a typical week in my home the dishwasher is run..	Every day or every other day =1
Locus of control	CNT_OVERR	How important is it for you to be able to override the automatic adjustments when you consider signing up?	Very important - Very unimportant Likert scale 7 points
Trust	TRST-INTG (integrity)	Please indicate how much you agree with the following statements. My electric company treats people like me fairly and justly.	Strongly Agree - Strongly Disagree Likert scale 7 points
	TRST-COMPT (competence)	Please indicate how much you agree with the following statements. I am confident in my electric company's skills.	Strongly Agree - Strongly Disagree Likert scale 7 points
	TRST-BEN (Beneficence)	Please indicate how much you agree with the following statements. My utility company always keeps the customers best interest in mind.	Strongly Agree - Strongly Disagree Likert scale 7 points
	TRST-CNTMUT Control mutuality)	Please indicate how much you agree with the following statements. When designing programs my electric company gives people like me enough say in the decision-making process.	Strongly Agree - Strongly Disagree Likert scale 7 points

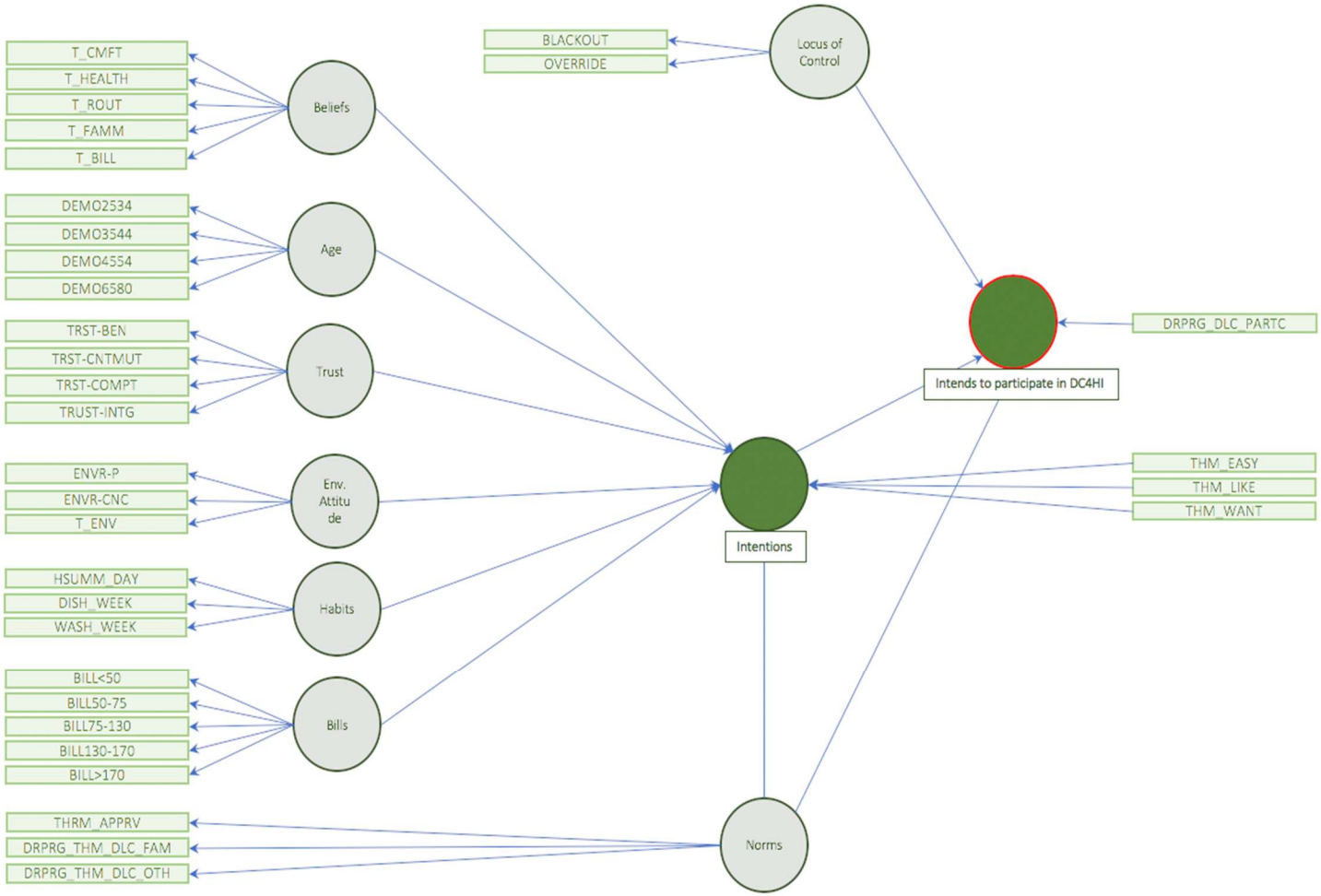

Figure 7: Structural model for the intention to participate in a DR program using connected thermostats

5.3.1 Program A: Automated control, short duration (4 Hours), large incentive ($50)

Program A was the choice of 314 survey participants (32 percent). This automated control program choice "offered" higher compensation ($50) for participation in an event for a short duration[8]. The result of the SEM-PLS calculations is presented in, Figure 15 in the Appendix. The model has reasonable explanatory power over intentions to participate in Program A (52%). Respondents who chose Program A and reported interest in participating in the program (AVE=5.6, std=1.4) were convinced that their family would be supportive and "others like them" would be interested changing the thermostat settings. Ultimately, their willingness to participate in an automated program was aligned with those intentions. Another interesting characteristic of this group is trust in the utility company, which has a moderate effect upon intentions to change the thermostat settings. The impact of automated control over household routines together with the effects over the environment are latent factors with opposite meanings: the impact of automated controls on household routines is viewed negatively, while a positive environmental impact is viewed favorably.

5.3.2 Program B: Voluntary control, long duration (6 Hours), large incentive ($50)

Program B was selected by 436 (R^2=44 percent) of the participants. Like program A, this option offered a high incentive ($50) for an event with a slightly higher duration of time (6 Hours)[9]. Participants who chose this option believed that the gain of having voluntary control over their connected thermostat was higher than the loss of having to "endure" a DR event for a more extended period. This effect is confirmed by the results of the structural equation model (Figure 16, in the Appendix), where the locus of control is the latent variable that has the higher influence over the intention to participate in the program. Social norms have a mild effect over those intentions to participate in a specific program (voluntary, high pay), but have a stronger impact on the more abstract concept. Finally, even though it didn't have a significant effect over the formation of intentions, the loadings of the indicators that formed environmental attitudes were consistently high, and therefore it appears that this segment was significantly more environmentally friendly than the other two segments.

5.3.3 Program C: Voluntary control, short duration (4 Hours), small incentive ($30)

Program C was selected by 235 participants (24 percent) of the participants. The program offered a low incentive for voluntary control, for a short period of time (4 Hours)[10] The trimmed model (Figure 17, in the Appendix) was able to explain 30 percent of the intentions to participate in the DR option selected by this survey segment. Similar to Program B, the locus of control is the latent variable with the higher explanatory power, and intentions to change the thermostat settings has a moderate effect in the decision to participate in the program selected. This segment believes that it would be uncomfortable to change the thermostat settings.

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[8] Your electric company will automatically increase the thermostat by 2°F for 4 hours. You will be receiving $50 per year for participating.

[9] You are asked to increase the temperature of your house by adjusting the temperature of the thermostat by 2°F for 6 hours. You will be receiving $50 per year for participating.

[10] You are asked to increase the temperature of your house by adjusting the thermostat by 2°F for 4 hours. You will be receiving $30 per year for participating.

5.4 Connected devices

Respondents were asked to rank several energy-intensive activities in the home (using the dishwasher, laundry, cooling, and showering) in the order that they could be automatically controlled by the utility on hot summer days (Figure 8). The sample was split into three groups to better observe age related differences (if they existed).

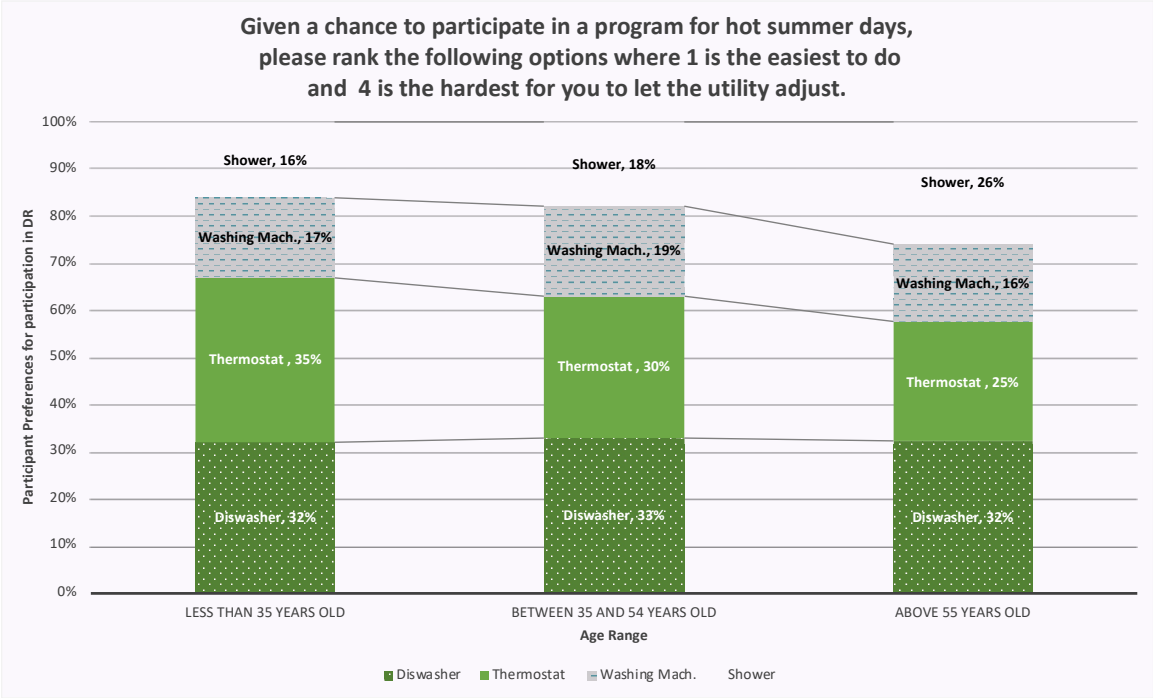

Figure 8: Preferences towards shifting household routines, by age group

Results show that the dishwasher and thermostat are the two connected devices that were rated more favorably for utility control across age groups. Older demographics (group 55+) are more flexible towards participation with connected water heaters, which is an effect observed previously, in other studies [23] reflecting the flexibility of shifting that activity, which is typical of those demographics[11].

5.5 Preferred modes of compensation for participation in an electric DR program

The survey explored several methods of compensation for participation in DR events. Participants were asked to rank four methods according to the following scenario: "Suppose that you have a chance to participate in a thermostat program during hot summer days. Your WiFi thermostat will be automatically adjusted, by3ºF, for no more than 4 hours. You will be compensated if your thermostat can be automatically controlled 40 out of 50 times over the Summer. How would you like to be

[11] It is doubtful that the participants would know that lowering the hot-water setpoint temperature by a few degrees for a few hours has a minimal impact on the hot-water temperature. A DR program focused on connected water heaters should take communication with the public very seriously and focus on the benefits of participation versus a negligible impact over the household routines.

compensated for your participation?" To observe if low-income participants had other preferences, the survey responses were split for income and household occupancy. Overall significant differences among groups were not found (Figure 9 & Figure 10).

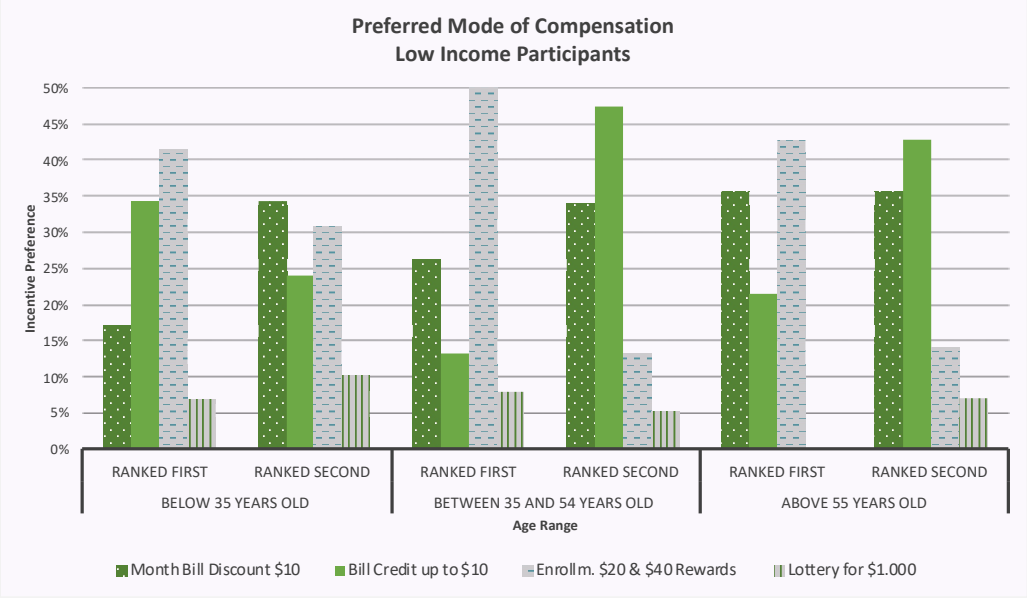

Figure 9: Ranked preferences of the preferred mode of compensation for participation in a DR program (low income)

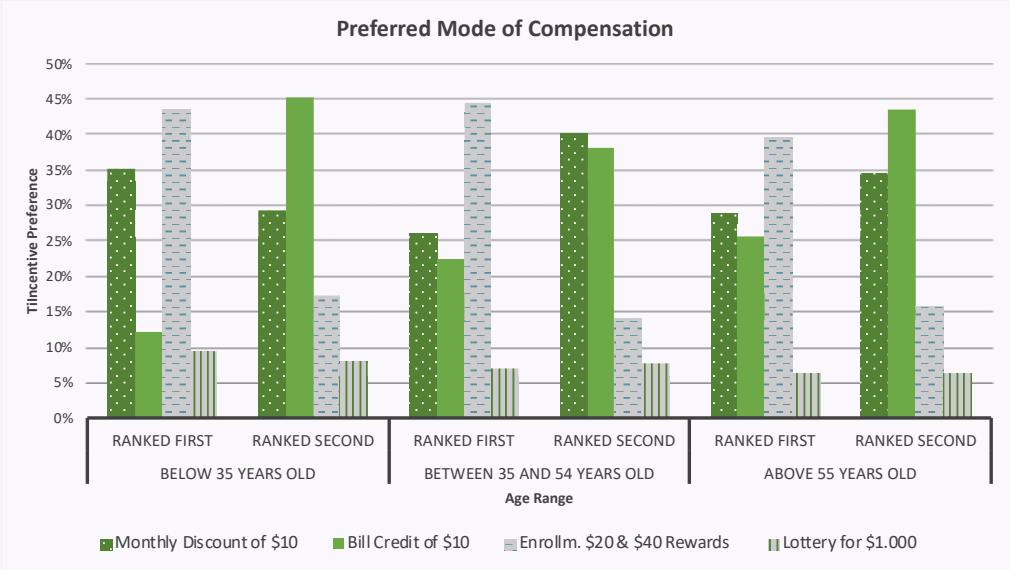

Figure 10: Ranked preferences for compensation for participation in a DR program

More traditional methods of compensation i.e., enrollment incentives, bill credits, or discounts, are ranked first across age groups, with "providing enrollment together with participation incentives" being selected first and the lottery being chosen last. Receiving a monthly discount by a fixed amount is the second preferred first choice. Receiving a bill credit is generally chosen second by the majority of the respondents except the group aged between 35 and 55 who picked monthly discounts second, very similar in preference with bill discounts (2% difference). Low-income respondents appear to have

identical preferences, choosing enrollment and incentive as the first option and bill credit second. Monthly discounts appear as the second category in the first choice.

6 Brief evaluation of the impact of community outreach techniques on the likelihood of customer enrollment

6.1 Background and Goal

Residential DR pilots have demonstrated significant demand reductions once customers enroll. However, their cost efficiency requires broad generalized voluntary enrollment. By relying on existing communication channels and socio-demographic contextual referents, community-based outreach techniques can make abstract concepts relatable to customers and build trust. The marketing materials were carefully designed to reflect other elicited concerns, such as focusing on customer goals and benefits, and program clarity, to make the communication process relatable and contextual in a cost-effective manner. In collaboration with National Grid, we chose two comparable 2017 Community Initiative towns[12]: Gloucester, MA, and Rockland, MA. The experiment was deployed late in the season (end of August), but it was still relevant because at that time it was unlikely that it coincided with other enrollment initiatives (by the thermostat vendors or by the utility), limiting potential bias. The objective of the experiment was to determine if community-based social marketing techniques could significantly increase enrollment in comparison with the control group, in the season when it was unlikely for customers to enroll.

6.2 Target communities

Two National Grid's Community Initiative towns in Massachusetts, were the targets of the community outreach experiment[13]. Of the group of communities enrolled Gloucester and Rockland, MA were considered comparable in terms of median household income and ethnicity (Table 11). Gloucester has twice the population and number of housing units as Rockland. To avoid introducing bias[14], in the number of enrolled thermostat units, we chose Gloucester for control.

Table 11: Characteristics of the target communities and comparison with the estimated data for Massachusetts (U.S. Census Bureau, quickfacts, estimated data, 2017).

	Gloucester, MA	Rockland, MA	Massachusetts
Role in Experiment	Control	Treatment	
Population	30,094	17,891	6,859,819
Total Housing units	14,827	7,238	2,585,715
Median Household Income	$65,348.00	$77,573.00	$74,167.00
Ethnicity			
White	94%	91%	72.2%
Hispanic	2%	2%	11.9%
Black	1%	3%	8.8%
Asian	1%	1%	6.9%
Other	2%	3%	0.6%

[12] The National Grid' Community Initiative Program, provides incentive grants of up to $40,000 to Massachusetts communities that meet the initiative's goals for implementing energy efficiency in their residential communities and achieving energy savings through energy assessments and implementation of measures.

[13] The Community Initiative program did not share any specific information about ConnectedSolutions, as it focused primarily on the dissemination and implementation of energy efficiency measures and not on demand response.

[14] If the enrollment rate is the same over time, a larger number of households would consequently result in a larger number of enrolled customers.

6.3 Outreach campaign

With the support of the Rockport Community Initiative Program Manager, the outreach campaign consisted of distributing flyers (Figure 11) and posters (Figure 12) in the Town of Rockland. The marketing materials were designed around the qualities of simplicity, ease, and straightforwardness, focusing on the customer's benefits for enrolling in National Grid's DR program.[15] The materials were distributed in local places of gathering (shops/businesses, restaurants/bars, clubs, churches and town buildings) to reach across age and social groups, as shown on Table 12.

Table 12: Collateral dissemination schedule

Type	Locations	Type of Collateral	Date
Places of prayer	First Congressional Church	Poster / Flyer	17-Aug
Places of prayer	Holy Family Church	Poster	17-Aug
Restaurants/bars	Anita Marie's	Poster	17-Aug
Restaurants/bars	Mikes Pizza	Poster / Flyer	22-Aug
Restaurants/bars	Rock Vegas Bar & Grille	Poster	17-Aug
Restaurants/bars	Corner Grill Rockland	Poster	17-Aug
Restaurants/bars	Yianni's Pizza	Poster	17-Aug
Clubs	Rockland Youth	Poster / Flyer	22-Aug
Shops/businesses	Theresa's Hair	Poster	22-Aug
Shops/businesses	Rockland Memorial	Poster / Flyer	22-Aug
Shops/businesses	LCT Computers	Flyer	17-Aug
Shops/businesses	GV Brazilian Store	Poster	17-Aug
Shops/businesses	Tedeschi Food Shops	Poster	22-Aug
Shops/businesses	Mountain One Bank	Poster	22-Aug
Shops/businesses	Rockland Federal Credit Union	Poster	22-Aug
Shops/businesses	Tildens Florist	Flyer	22-Aug
Shops/businesses	Couture Dry Cleaners	Flyer	22-Aug
Shops/businesses	Rockland Athletic Store	Poster / Flyer	17-Aug
Shops/businesses	Metal Detector Store	Flyer	17-Aug
Town building	Rockland Public Daycare	Poster / Flyer	22-Aug
Town building	Town Hall Website Posting	Digital Flyer/Poster	17-Aug
News	Wicked Local Posting	Digital Flyer	17-Aug
News	Rockland / Abington Mariner	Flyers	16-Aug

[15] Fraunhofer USA CSE designed the marketing materials, which were reviewed and approved by National Grid for dissemination.

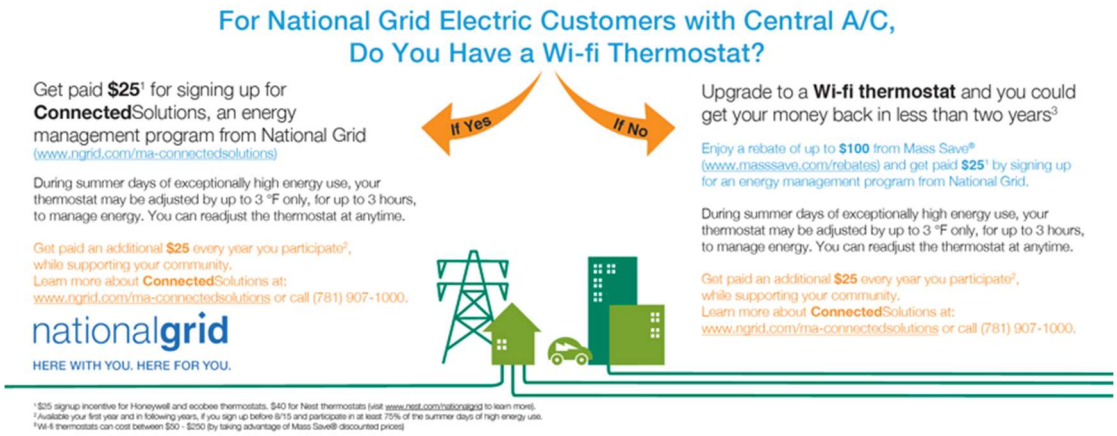

Figure 11: Collateral - Flyer

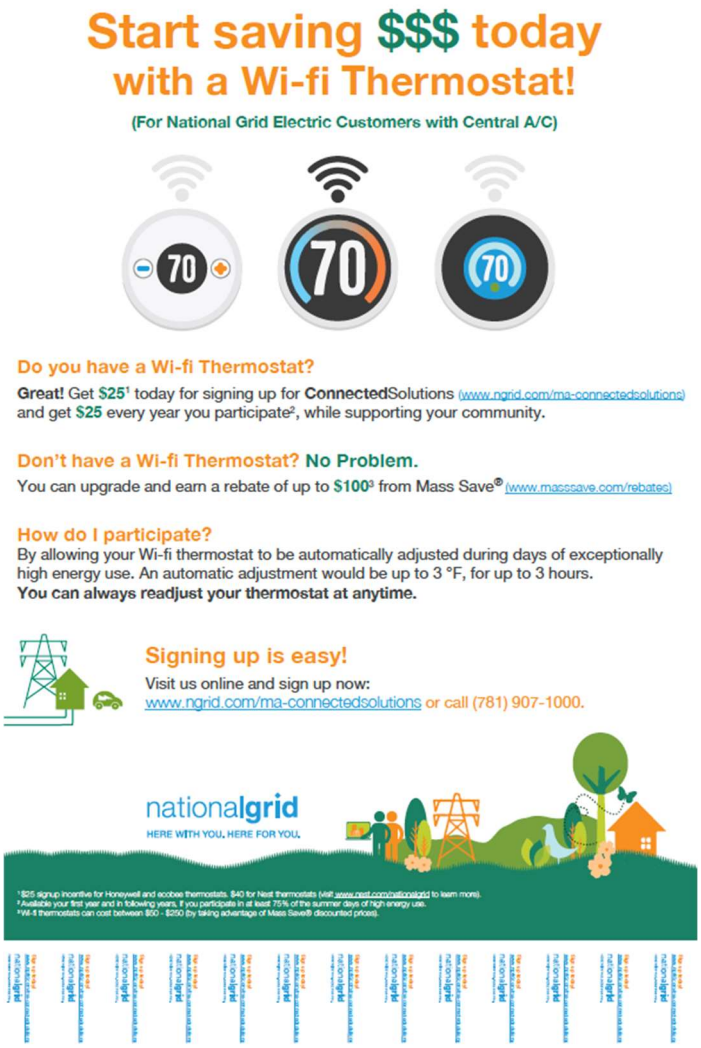

Figure 12: Collateral - Poster

The flyers and posters were distributed on two days (17 and 22 of August 2017) and remained on display for another week, until the end of the month. The digital flyers were on display for the same period of time. Coincidently, towards the end of the month the average daily temperature and consequently decreased, which was reflected in a decrease in cooling needs (CDD; Figure 13).

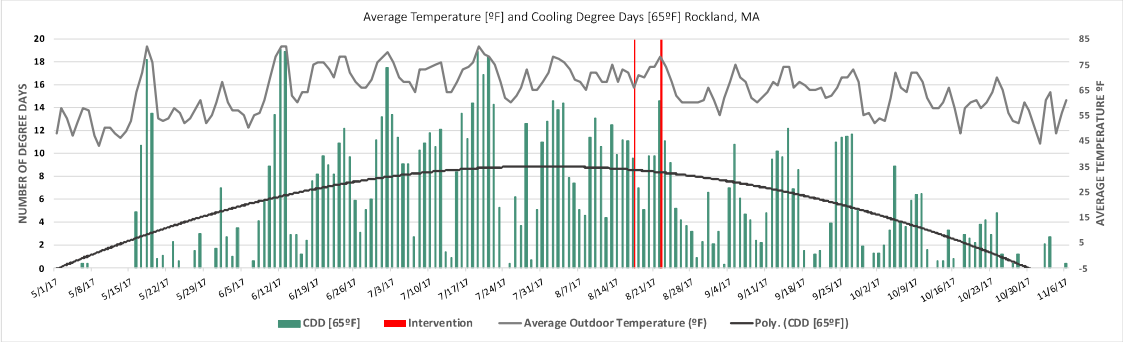

Figure 13: Average outdoor temperature and cooling degree days between May and November 2017 for Rockland, MA

6.4 Results

Between August 31, 2017 and January 12, 2018, no thermostats were enrolled in Gloucester, and six thermostats were enrolled in Rockland (Nest=3 and Honeywell=3). Because Nest has traditionally been more successful in enrolling customers, to prevent any biases, the analysis of the effect of the intervention focused solely on the enrollment of Honeywell thermostats. Resistance to enrollment in this type of program is high, and only three Honeywell thermostats were enrolled in the Town of Rockland between August 31, 2017 and January 12, 2018. As explained, none was installed in Gloucester during the same period, despite having twice the number of households as Rockland (Figure 14). Next, we determined if the trend of enrollments in Rockland was "normal" in comparison with the installation trend in the rest of Massachusetts.

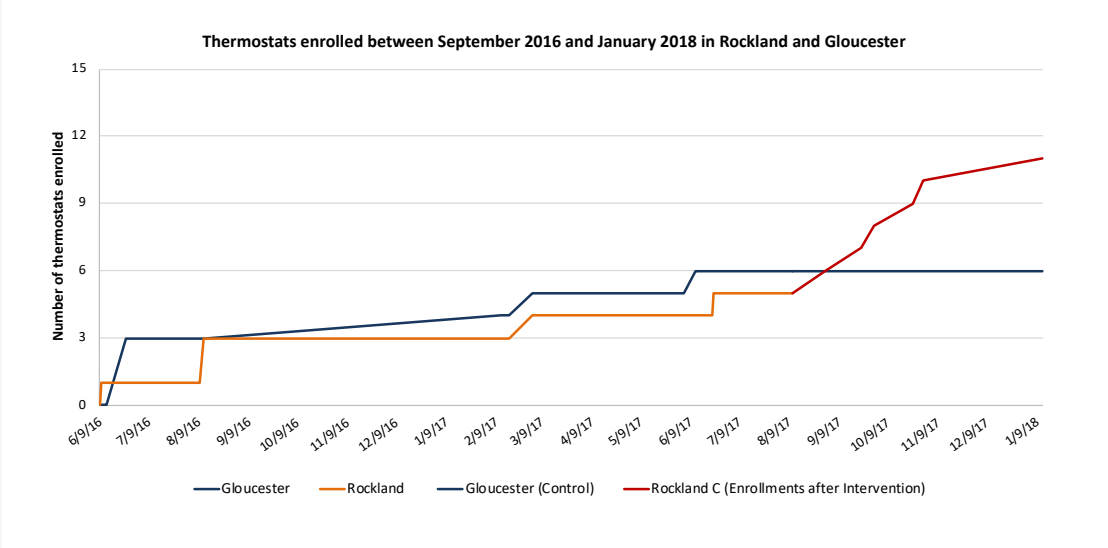

Figure 14: Thermostat enrollments, in ConnectedSolutions, in Rockland and Gloucester

The model assumes National Grid's service area to be 40% of the total number of households in Massachusetts, and a rate of connected thermostat ownership of 13% [25] (Table 13: Parameters of the model). The Z statistic was used to determine if the difference in proportions between the number of installed thermostats and the total number of potential targets was significant. The test showed that with a Z= 2.4 (p=0.001) the difference was significantly different: which could signify that if everything else was stable and there had been an effort to contextualize the marketing dissemination campaign across

Massachusetts, just for a week, National Grid should expect an enrollment rate between 534 and 267 Honeywell thermostats [0.003 ± SE(0.001] during August 31, 2017 and January 12, 2019.

Table 13: Parameters of the model

	Rockland	Gloucester	Massachusetts
Total households	6,697	12,486	2,585,715
National Grid's service area (100%&40%)	6,697[16]	4,994	1,034,286
13% Penetration CT	870	1,623	134,457
Enrollments during experimental period	3	0	147
Installations by household	0.003	0	0.001

[16] Rockland and Gloucester are 100% covered by National Grid

7 Conclusions and recommendations

The study found several aspects that can improve demand response program design and delivery.

Program design

Override. The option to override and opt out of demand response events is a key latent factor that significantly explains customers' preference for voluntary instead of automated demand response programs. Even though voluntary demand response programs are not a novelty, automation awards utilities the opportunity to achieve more predictable peak demand reduction goals. Opt-out and override options should be a centerpiece of program design, and communication of these program aspects with the customers should be carefully designed and tested.

Comfort: For a small group of survey participants who are most averse to participation in demand response programs, losing comfort (together with locus of control) is a significant concern. Therefore, communication with the customers should also focus on maintaining comfort and the ease/convenience of participation.

User experience: Too often, programs, systems and applications are designed with a focus on business goals and technological capabilities but forget that they require massive customer engagement to be successful, largely ignoring the needs of the customer-user. Involving the user early on in the design process will help tailor the language used to convey complex ideas to different market segments. It will also help avoid functional and technical interface flaws that can frustrate users and keep them from enrolling or engaging with the software platform.

Other connected enabled appliances: Across age groups, dishwashers and washing machines, together with the more conventional WiFi (connected) thermostat, are natural candidates for demand response. The habit of showering at a particular time is the hardest to modify, but the impact of DR over the temperature of the water in the water heater is minimal. Therefore, all communication involving automating water heaters needs to be carefully designed to reduce customers' concerns about convenience and comfort and increase enrollment.

Incentives: Enrollment incentive and participation reward were the most popular option, closely followed by a monthly discount, which indicates that costumers favor constancy and certainty. Incentives for referral of friends or family, should also be included.

Customer testimonials and mass marketing. User feedback indicated that other customer testimonials about their experience with the DR program were a pivotal attribute to entice participation. Participant testimonials were going in parallel with advertising the program on mass media and taking advantage of economies of scale realized through other cross-marketing media. These include promotions on the website, bill inserts, TV, newspaper, and radio advertisements.

Wording of the marketing materials: The language used to disseminate information about the program should be relevant to the socio-cultural context of the target population and should focus first on the customers' benefits. It should also be related to the population beliefs and attitudes and, for example, focus on "savings" and "comfort."

Program delivery

The role of aggregators and vendors: Previous research [5] has found that customers who mistrust utilities are less willing to participate in direct-load control programs. In our study in Massachusetts, we concluded that the customers overall don't seem to openly distrust utilities. But we also found that the customers are more open to accept direct control over their connected devices if that control is performed by those vendors instead of the utility. Therefore, collaboration between utilities and connected device companies would likely increase engagement and participation of customers.

Community-based marketing: By relying on existing communication channels and socio-cultural referents, community-based outreach techniques can make abstract concepts relatable to customers and build trust. The small experiment conducted in the scope of this study showed that community based social marketing are productive in increasing customer awareness and incentivizing enrollment. The campaign was based on low-cost measures and techniques that can be easily implemented to maximize enrollment.

8 Lessons learned and Replicability

The study found that program design should take advantage of existing technology, such as AMI and smart appliances. AMI enables the design of new types of pricing schemes that together with connected devices allow for multiple choice of DR programs. To overcome the reluctance of customers to enrolling in DR programs, utilities should communicate with the customers in terms that make sense to each market segment. They should also capture economies of scale and establish partnerships with other partners/vendors and cross-sell their programs.

Programs should also be designed for their context: Over time, several types of connected devices have been integrated into residential DR programs. Due to their independence from an AMI infrastructure, communicating thermostats give utilities the opportunity to offer residential DR where an AMI infrastructure does not exist.

In such cases, savings and effective participation are directly calculated from the thermostat's interval data, which partially explains the popularity of such programs. Smart switches and other enabling technology are an intermediate alternative to include water heaters and air conditioning systems in residential DR programs, with the advantage of enabling control of larger residential loads potentially interesting for demand response.

9 Project Team

This study was conducted by Fraunhofer USA Center for Sustainable Energy Systems, in collaboration with National Grid.

Fraunhofer CSE:

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10 Appendix: SEM-PLS models [26]

10.1 Program A

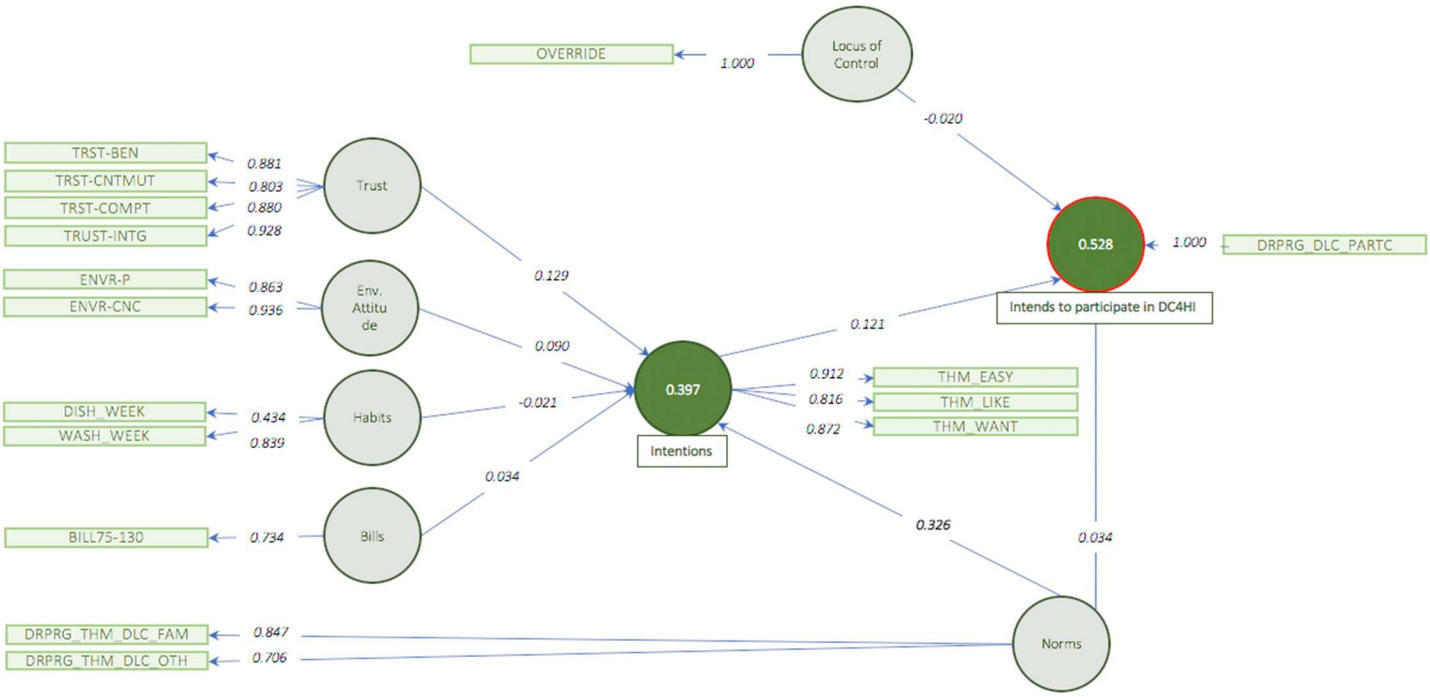

Figure 15: Trimmed SEM-PLS model for Program A

10.2 Program B

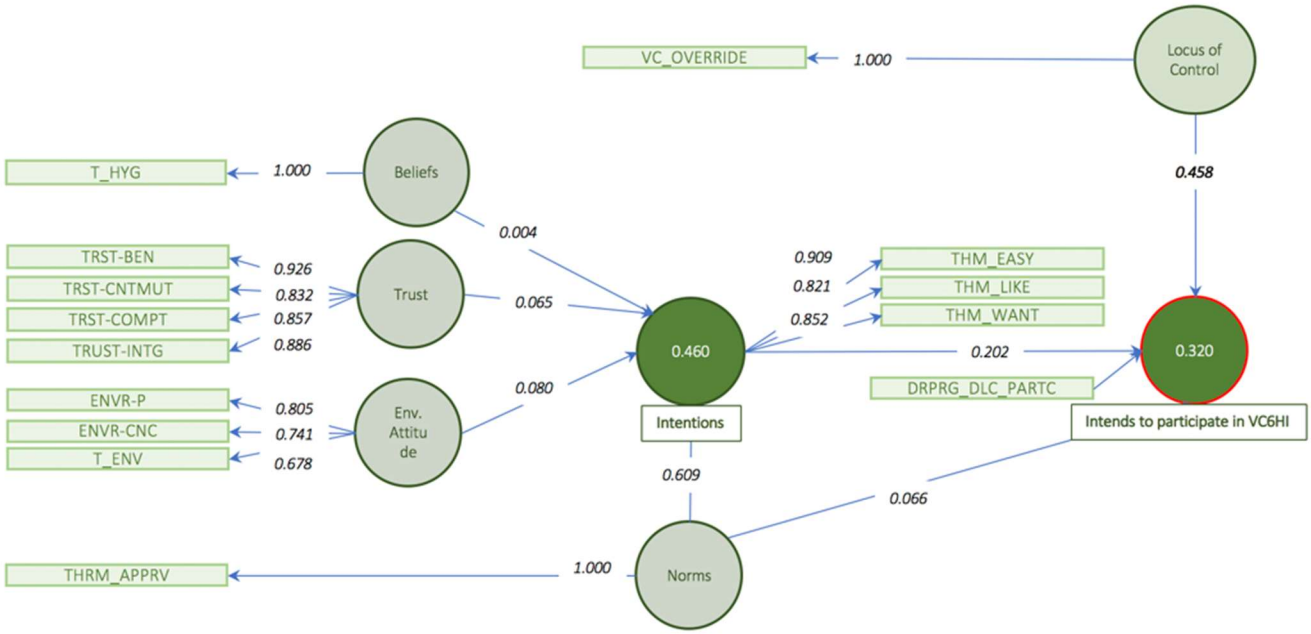

Figure 16: Trimmed SEM-PLS model for Program B

10.3 Program C

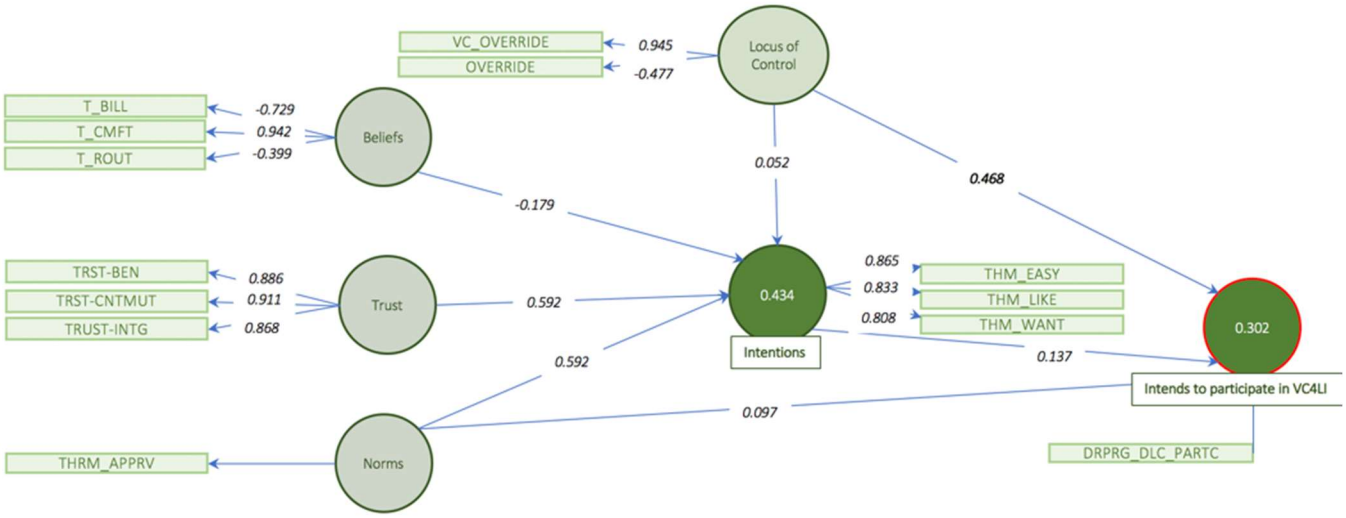

Figure 17: Trimmed SEM-PLS model for Program C