

## 2011 EM&V Report for PSE Residential Demand Response Pilot Program

### Contents:

- 2011 EM&V Report for PSE Residential Demand Response Pilot Program
- Evaluation Report Response

This document contains both the final **2011 EM&V Report for PSE Residential Demand Response Pilot Program** produced by Navigant Consulting, and the Puget Sound Energy **Evaluation Report Response** (ERR). PSE program managers prepare an ERR upon completion of an evaluation of their program. The ERR addresses and documents pertinent adjustments in program metrics or processes subsequent to the evaluation.

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**2011 EM&V Report for the  
Puget Sound Energy  
Residential Demand Response  
Pilot Program  
Final Report**

**Presented to:**

**Puget Sound Energy**

**Prepared by:**

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## Section 1. Executive Summary

The Puget Sound Energy (PSE) Residential Demand Response (DR) Pilot was designed to assess the peak demand reduction achievable through the control of residential space and water heating equipment, and the level of customer acceptance of that control. This report evaluates the demand impacts of the program as well as providing an evaluation of program processes and achievements related to customer recruitment, equipment installation and performance, and customer satisfaction.

### *1.1 Pilot Program Overview*

The Residential DR pilot was a residential load curtailment program that ran from October 2009 through September 2011 under the utility's Electric Schedule 249A filed tariff. PSE is a winter peaking utility, typically experiencing system peak demand during brief periods of cold weather occurring between November and late February. Summer temperatures across much of the utility's service area are generally mild in comparison to other parts of the US. Periodic, brief periods of hot weather, normally with low humidity, can occur in intermittent years.

This pilot was conducted on Bainbridge Island, located in Puget Sound in the western portion of the PSE service area. Electric space and water heat customers served by circuits fed from two older substations were targeted for pilot recruitment. Natural gas service is unavailable on the island, and a high percentage of homes use electric space and water heat. The population of the island has increased from approximately 12,000 in 1980 to more than 23,000 in 2010.

Two of the island's three substations regularly experience high morning and evening loads under winter cold weather conditions. PSE has worked with local community groups that have expressed interest in supporting options for reducing cold weather peak electrical loads placed on the two substations. The pilot was accepted by the groups as one potential strategy that might aid in providing substation peak relief and possibly delay the need for construction upgrades to the local transmission and distribution system.

The broader goals of the pilot included the following:

- Test the feasibility of a technology-based residential demand response program and the impact on demand that such a program can have
- Evaluate the technology requirements and performance
- Understand customer tolerance and acceptance
- Determine potential peak electric demand reduction during the winter (November through February) and summer (June through September) curtailment seasons.



With a high community penetration rate (estimated at more than 80%), commercial broadband Internet service was selected for two-way communications between the pilot’s control devices installed in participants’ homes and the head-end demand response management software. The software was accessed by PSE to control the electric space and water heat loads during curtailment events and provided data reporting to PSE. All enrolled participants were existing subscribers with one of the island’s commercial broadband internet service providers.

Two vendors supported this pilot. These vendors were selected in a national competitive RFP solicitation. The selected equipment and software vendor (ESV) provided the hosted head-end demand response management software service, as well as hardware: compatible load switches, communicating thermostats and digital Internet gateways. An implementation team external to PSE was contracted to manage customer enrollment, electrical installation permit applications, equipment installation in participant homes and follow-on troubleshooting and service. Licensed electrical technicians employed by an electrical contractor provided field services under the management of the external implementation team.

Electric space heating and water heating were cycled during winter control events. In summer, only heat pumps (in cooling mode) and water heating loads were shed during events. Pilot recruitment began in October of 2009. Most participants enrolled by January of 2010, shortly before the first curtailment event for which data exists was called. Approximately 530 participants out of a targeted population of approximately 6,700 customers on Bainbridge Island, or about 8% of its target population were recruited, enrolled and retained. Strong support of the pilot by local community groups, extensive local media promotion and individual social networking contributed to a higher enrollment rate compared to typical utility experience.

Participants could elect to have just their water heater, just their space-heating equipment<sup>1</sup> or both their water heater and space-heating equipment controlled by PSE during the pilot. Some participants with electric water heaters also had a non-electric heat source, such as propane, which was not controlled. A summary of the devices participating in the program is provided in Table 1, below. The dots in the table indicate the group within which each customer count falls – for example, there were 193 participants that had only a water heater control device installed, 51 that had a water heater and baseboard control device installed, etc.

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<sup>1</sup> Heat pumps, one of the types of space-heating equipment controlled, also provide space-cooling in the summer months.

**Table 1: Summary of Participating Devices**

Water Heater	Heat Pump	Electric Furnace	Baseboard	Number of Participants
•				193
•			•	51
•		•		46
•	•			208
			•	2
		•		3
	•			25
Total Number of Participants:				<b>528</b>

*Source: External implementation team database*

## 1.2 Evaluation Methodology

The approach to the pilot evaluation was divided into two major components: 1) estimating load impacts and 2) assessing program processes and customer perceptions.

### 1.2.1 Impact Evaluation Methods

The evaluation team estimated demand response impacts using interval meter data and an econometric technique known as “fixed effects regression,” a common technique for estimating the impacts of energy efficiency and demand response programs. The regression uses longitudinal (panel) data. A panel data set is one composed of a series of discrete observations made over time on a group of different individuals. Fixed effects allow the analysis to control for a variety of differences between individuals that do not vary with time. For example, a participant with a very large house will tend, on average to consume more electricity than one with a small house. Not controlling for house size when attempting to estimate the impact of a treatment on both customers will lead to bias in the results. The same would hold true, for example, with a customer whose house has many windows.

By including a fixed effects term in the regression model, the analysis controls for all of these time-invariant differences between customers without the need for explicitly including corresponding explanatory variables in the equation.



### 1.2.2 Process Evaluation Methods

The process evaluation provided an in-depth understanding of customer and staff experience with the pilot that can be used to help assess whether to offer a large-scale program and, if so, to inform program design and delivery. The ultimate goal of this research was to provide PSE with recommendations for long-term optimization of program value.

The evaluation research was primarily based upon the following three research components:

- In-Depth Interviews with Program Contractors and Delivery Staff.
- Telephone Survey of Participants, Past Program Participants (“dropouts”), and Non-Participants
- Focus Groups of Participants and Dropouts

Sample sizes for each of these three research components are provided in Table 2.

**Table 2: Process Evaluation Study Methods and Subjects**

Study Method	Subject Groups	Number of Individuals
In-Depth Interviews	<ul style="list-style-type: none"> <li>• 3 PSE Staff</li> <li>• 2 Staff members of the external implementation team</li> <li>• 2 Staff members from the equipment and software vendor (ESV)</li> <li>• 1 Staff member from the electrical contractor (<i>Managed by the external implementation team</i>)</li> </ul>	8
Telephone Survey	Participants, dropouts, non-participants	143
Focus Groups	Participants, dropouts	14

*Source: EMI Analysis*

**In-depth interviews** were conducted with: 3 PSE Program Staff, 2 Staff members of the external implementation team, 2 Staff members from the equipment and software vendor (ESV) and 1 Staff member from the electrical contractor in May of 2011. These individuals held the following roles:

- Outgoing PSE Program Manager
- PSE Manager of New Program Development and Evaluation
- PSE Senior Market Analyst

- ESV Project Manager
- ESV Technical Services Manager
- External implementation team VP of the Western Region
- External implementation team Field Project Manger
- Electrical contractor Electric technician (*Managed by external implementation team*)

The objectives of the in-depth interviews were to gain a more thorough understanding of program processes and to identify specific areas of program delivery where inefficiencies and/or areas in need of improvement may exist. The interviews were primarily intended to provide qualitative information, and the small sample size does not allow adequate statistical precision to make judgments about the representativeness of the samples.

The **telephone survey** was intended to solicit responses from statistically significant samples of participants, dropouts, and non-participants in order to evaluate customer demographics, awareness and knowledge of the program, satisfaction with installation and customer service, motivations to participate, experience with curtailment events, and interaction with technologies. Survey respondents were encouraged to describe their experiences to inform qualitative analysis of program strengths and areas in need of improvement. Demographic data were collected to characterize the participant population relative to the Bainbridge Island community.

The evaluation team conducted two **focus group sessions** with a total of 14 customers on Bainbridge Island on June 14, 2011. The first focus group consisted of individuals who were actively participating in the pilot. The second group consisted of individuals who had initially joined the program and have since ended their participation. The results of these focus groups can be used to inform the future demand response program efforts that PSE may pursue, in particular influencing the design and educational components of future programs.

The focus group method allows the researcher to observe group dynamics and understand how opinions are structured in a manner not possible through other primary research methods, such as surveys or in-depth interviews.

### ***1.3 Program Impact Findings***

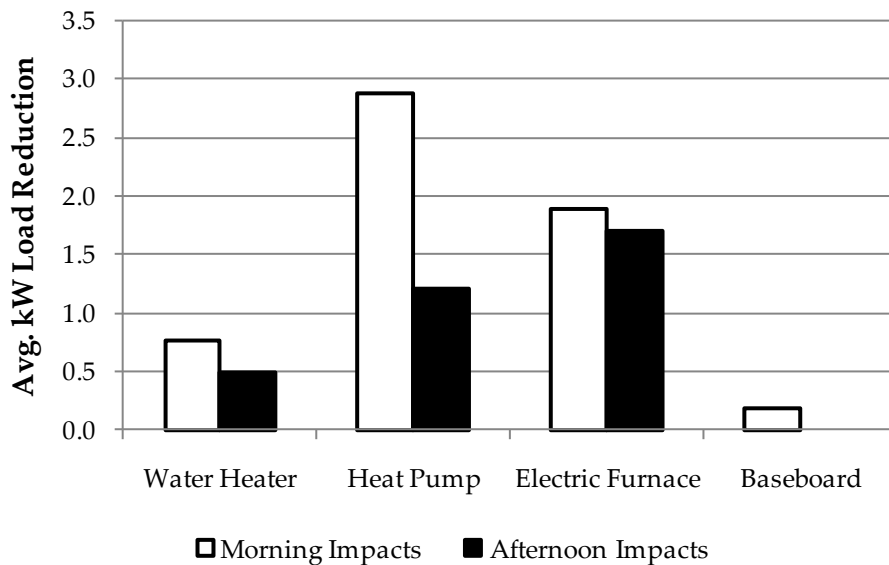
Generally speaking two types of impacts are presented in this report: 1) demand reductions due to PSE-initiated control events, measured as the average demand reduced due to curtailment

and 2) snapback impacts, which refers to the increase in household demand that follows the end of a curtailment period.

Curtailment impacts were estimated for each type of device as the average load reduction over the course of the events. As may be seen in Figure 1 and Table 3, on a device-by-device basis, the greatest demand impact was made by heat pump curtailment during morning events, followed by electric furnace curtailment in both the morning and the (late) afternoon. Baseboard heater impacts were found to be very small in the morning and non-existent for afternoon events.

**The estimated impacts shown below are the average per-device impact of a *successfully controlled device*.** A successfully controlled device in this case is defined as a device (or end-point) that the implementation contractor was able to verify actually responded to the curtailment signal. The overall percentage of successfully controlled devices (i.e., devices which received the signal to modify operation) ranged from 57% for water heaters to 75% for baseboard heaters, as shown on the bottom row of Table 15. The majority of non-responsive end-points were non-responsive to all of the events called.

**Figure 1: Average Impact per Successfully Controlled Device – Winter (Chart)**



Note: Impacts in this chart and the charts and tables which follow are averages across successfully controlled devices unless otherwise noted in the text.

Source: Navigant analysis

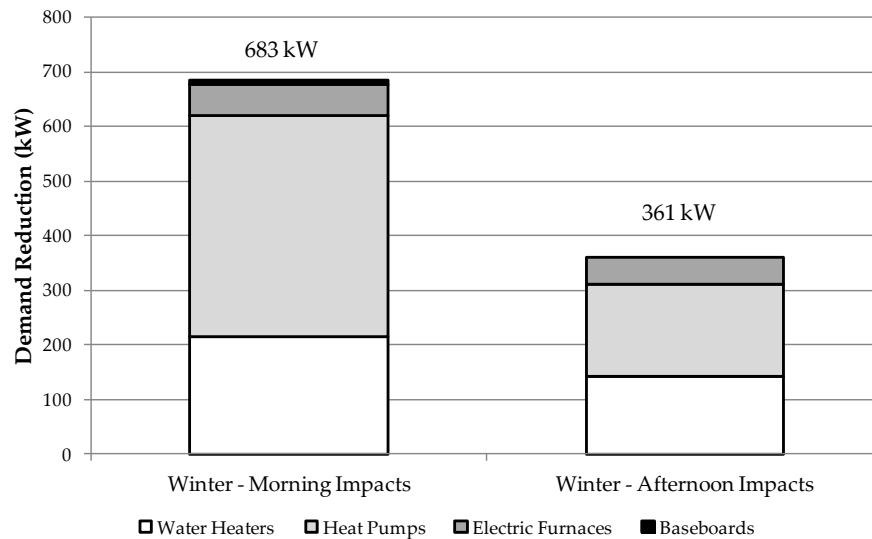
**Table 3: Average Impact per Successfully Controlled Device – Winter (Table)**

	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards
Morning (kW)	0.77	2.88	1.88	0.18
Afternoon (kW)	0.49	1.21	1.71	0.00
Average % of Devices Successfully Curtailed	57%	64%	64%	75%

Source: Navigant analysis

The average aggregate impact that the pilot had on Bainbridge Island load for winter morning and winter afternoon events, split up by type device curtailed, may be observed below in Figure 2. Note that while an electric furnace’s individual average demand savings are very high, electric furnaces account for fewer than 10% of the controlled devices, resulting in a relatively small aggregate average impact.

**Figure 2: Average Aggregate Impact – Winter (Chart)**



The precise figures making up Figure 2, as well as the average percent of load switches that responded to the control signal are shown in Table 4 and Table 5 below. Note that there is a considerable difference between the aggregate impact in the morning and the afternoon of both water heaters and heat pumps. Water heater curtailment yields a much greater impact in the morning due to hot water use typically being greater in the morning than in the afternoon (showering). Heat pump curtailment yields a much greater impact in the morning due to the fact that on very cold winter mornings the heat pump must engage its (very inefficient)

auxiliary resistance heat strips in order to supply the heating load. This auxiliary heat is considerably less efficient than the standard heat pump operating mode (which is what is used to heat the house in the afternoon, when it is warmer). Thus curtailment impact in the morning is really the impact of curtailing electric resistance heat, whereas the curtailment impact in the afternoon is the impact of curtailing a (much more efficient) heat pump. Further discussion of these two findings may be found below in 1.3 and Section 4.

**Table 4: Average Aggregate Impact – Winter Mornings (Table)**

	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards	Total
Average Aggregate Impact (kW)	215	404	57	7	<b>683</b>
Average # of Participating Devices	478	219	47	53	
Average # of Devices Successfully Curtailed	272	140	30	40	
Average % of Devices Successfully Curtailed	57%	64%	64%	76%	

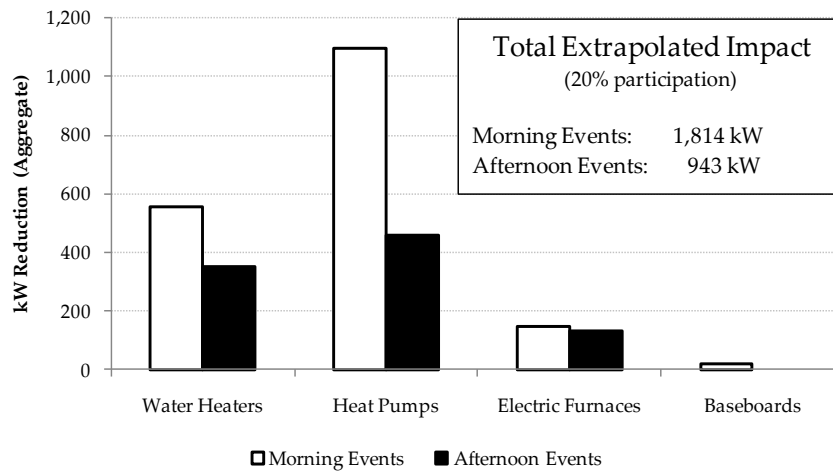
**Table 5: Average Aggregate Impact – Winter Afternoons (Table)**

	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards	Total
Average Aggregate Impact (kW)	141	171	50	0	<b>361</b>
Average # of Participating Devices	480	218	47	53	
Average # of Devices Successfully Curtailed	291	141	29	40	
Average % of Devices Successfully Curtailed	61%	65%	62%	75%	

One of the objectives of the pilot was to estimate the potential impact that would result from the wider deployment of such technologies in a future program in the electric service area. Using Bainbridge Island as an example, the evaluation team extrapolated the aggregate demand impacts for winter events if PSE were to be successful in recruiting 20% of its approximately 6,700 Bainbridge Island customers to participate in a residential DR program. These

extrapolated aggregate impacts assume that the distribution of devices would be identical to that of the pilot, that the same percentage of end-points would be successfully curtailed as in the pilot, and that the pilot participants are representative of the broader Bainbridge Island population. Under these assumptions, a winter program could be projected to provide nearly 2 MW of curtailments in the mornings and nearly 1 MW in the afternoons (Figure 3).

**Figure 3: Extrapolated Aggregate Impact by Device Assuming 20% Participation - Winter**

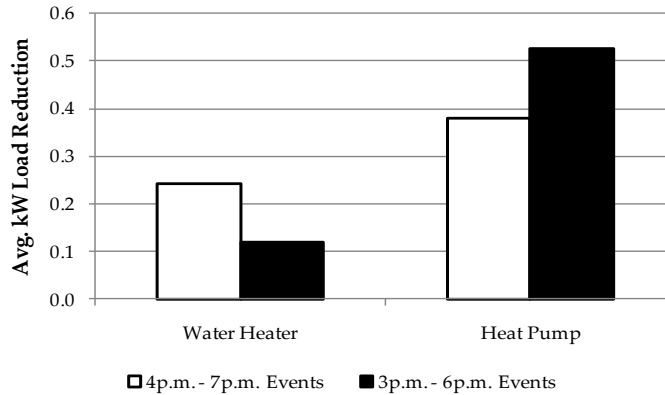


Note: Aggregate impacts above assume the same percentage of successfully controlled devices as observed in the pilot.

Source: Navigant analysis and the ESV's signal data

The evaluation also addressed the demand impacts of summer curtailment. In the summer of 2010, PSE called five events, two from 3p.m. to 6p.m. and three from 4p.m. to 7p.m. The per device demand impacts are presented below in Figure 4. The heat pump load reductions of approximately 0.5 kW are significantly less than the roughly 1 kW impact achieved by many summer air conditioning curtailment programs. However, it is consistent with programs in far northern regions where per-customer cooling demand is relatively low.

**Figure 4: Average Impact per Successfully Controlled Device – Summer (Chart)**



Source: Navigant analysis

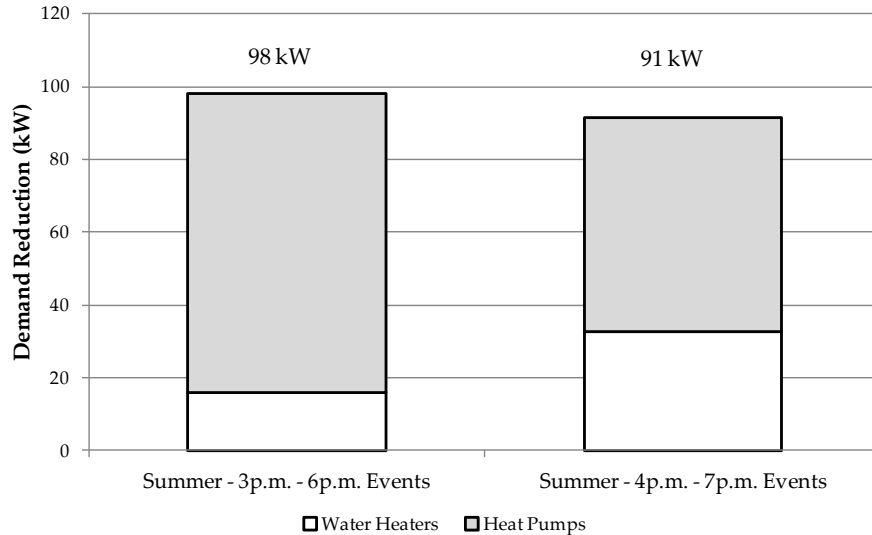
**Table 6: Average Impact per Successfully Controlled Device – Summer (Chart)**

kW	Water Heaters	Heat Pumps
4p.m. - 7p.m. Events	0.24	0.38
3p.m. - 6p.m. Events	0.12	0.53

Source: Navigant analysis

The average aggregate impact that the pilot had on Bainbridge Island load for summer events between 3p.m. and 6p.m. and for summer events between 4p.m. and 7p.m., split up by type device curtailed, may be observed below in Figure 5.

**Figure 5: Average Aggregate Impact – Summer (Chart)**



The precise figures making up Figure 5, as well as the average percent of load switches that responded to the control signal are shown in Table 7 and Table 8, below. The principal driver of the difference in impacts observed between the two types of events is the temperature at the time of the event on the days in question. Because there were so few of the two types of summer events, the average impacts are more susceptible to being skewed by weather than for those estimated for the winter events. More detailed discussion of these differences may be found in Section 5.

**Table 7: Average Aggregate Impact – Summer 4p.m. – 7p.m. Events (Table)**

	Water Heaters	Heat Pumps	Total
Average Aggregate Impact (kW)	16	82	98
Average # of Participating Devices	486	225	
Average # of Devices Successfully Curtailed	133	155	
Average % of Devices Successfully Curtailed	27%	69%	



**Table 8: Average Aggregate Impact – Summer 3p.m. – 6p.m. Events (Table)**

	Water Heaters	Heat Pumps	Total
Average Aggregate Impact (kW)	33	59	91
Average # of Participating Devices	486	225	
Average # of Devices Successfully Curtailed	133	157	
Average % of Devices Successfully Curtailed	27%	70%	

Observations from the evaluation team and additional detail of findings by device type are presented below:

### 1.3.1 Water Heaters

- At the individual household level, control of water heaters provides a relatively modest amount of demand response. However, these appliances account for perhaps the greatest potential for more widespread implementation, given number of electric water heaters on Bainbridge Island, and it appears that very few participants were inconvenienced or even noticed it.
- The demand response potential of water heaters is greatest in the morning, presumably when hot water demand for showers is highest. Curtailment of this device in the afternoon (when fewer participants tend to be at home using hot water) yields only modest savings compared with morning curtailment, as illustrated in Table 6 above.
- Water heaters curtailed in the afternoon (in winter and summer) exhibit snapback impacts that are actually greater in magnitude than the curtailment impacts. This result may be due to the fact that water heaters are typically used relatively little during the three afternoon hours when the events were called (and thus there is little opportunity for load reductions), and the post-event recovery is concentrated in the single hour after the event is over.

### 1.3.2 Heat Pumps

- Heat pumps have enormous DR potential for a winter-peaking utility because on very cold mornings they often engage their auxiliary (usually relatively inefficient) resistance heating to supply a home’s heating.

### 1.3.3 Electric Furnaces

- Of all the devices curtailed, electric furnaces provided the most consistent demand response impacts, both in terms of reduced demand and the magnitude of snapback.

### 1.3.4 Baseboards

- Baseboard electric heat (or fan-equipped electric wall heaters) cycled with load switches contributed relatively little load reduction. One possible explanation is that the main reason for baseboards' minimal demand impact is that not all baseboards in a participating home were connected to the control device and that curtailment of some just led to higher levels of consumption in others, thereby negating most of the demand reductions.

## 1.4 Process Findings

This section summarizes key findings from the research components of the study and synthesizes the results to produce recommendations. The evaluation team considers the DR Pilot to be a success insofar as pilot programs are expressly employed to identify potential issues for large-scale implementation. Furthermore, overall satisfaction was high among participants. Nevertheless, the key recommendations highlighted below should be considered if the program is re-implemented or expanded in the future.

***Finding #1: Overall, participants were satisfied with their experience in the Bainbridge Island Demand Response Pilot and would recommend it to others.***

Customers were generally satisfied with the DR Pilot. More than three-quarters of participants expressed interest in remaining in the program and would recommend it to a friend. A large majority of participants thought that the annual incentive payment was sufficient compensation for participation in the program.

***Finding #2: Many customers were motivated to participate in the program by altruistic reasons; dropouts cited varied reasons for leaving.***

Overall, participants and dropouts indicated they were motivated to participate in the Pilot more by altruistic and environmental reasons than by a desire to save money or receive an incentive. To "take an active role in energy conservation" was the most frequently cited motivation for participation by participants. Dropouts cited a variety of reasons for discontinuing participation, including equipment problems, physical discomfort, and increased utility cost. However, no specific trends were identified.

Some dropouts cited increased energy costs as their reason for leaving the program, which may be related to heat pump “snapback” issues. Participants generally expected to save money through their enrollment, and some participants expressed familiarity with and openness to adopting time-of-use rates.

***Finding #3: Most participants remained comfortable during curtailment events and maintained their normal activities.***

While overall satisfaction with curtailment events was high, it varied across the participants’ technologies that were controlled. Although a large majority of participants with enrolled water heaters, baseboard heaters, or forced air furnaces remained comfortable and undisturbed during curtailment events, more than half of heat-pump participants reported needing to take alternative actions to stay warm during events. Most heat pump participants recalled experiencing an event, whereas less than half of water heater participants could recall an event occurring.

***Finding #4: Participants did not exhibit a complete understanding of the program and demand response, although awareness of the program was high throughout the population.***

Program awareness was high among non-participants and participants alike, with the vast majority of them viewing the promotional letter as an effective means of communication. Newspaper articles also appeared to be a successful means of building widespread familiarity with the program. However, the majority of participants and non-participants did not demonstrate an understanding of demand response, either professing uncertainty or providing a response that did not reflect an understanding. Many participants expected to save money on their utility bills despite there being no mention of such a benefit in program materials. Lastly, some participants continued to express reservations about loss of control over heating, which might reflect unfamiliarity with the available option to opt out of up to 50% of events by request.

***Finding #5: Participants were generally dissatisfied with program technologies, particularly the Digital Gateway and programmable thermostat.***

Difficulties with program equipment appeared to be the largest factor in customer dissatisfaction with the program. Network connectivity was inconsistent for many customers, with roughly 15% of customers typically disconnected at a given time. Participants found the programmable thermostat difficult to operate, lacking in desired features and later, because of a manufacturer voluntary product safety recall, a potential safety hazard. Only half of participants were satisfied with the website. However, satisfaction with technologies was higher among those with enrolled water heaters. If PSE decides to expand the program, PSE may want

to consider providing a more seamless user experience by extensive pre-testing of proposed equipment and the adoption of different equipment than that employed in the pilot. Implementation staff speculated the high rate of connectivity loss could be due to malfunctioning communications equipment that did not immediately reconnect after local electrical power interruptions. PSE also provided reminders to customer to keep their gateways plugged in to a wall outlet or to leave the power strip energizing to keep the gateway switched on.

***Finding #6: Technicians and participants experienced numerous challenges in installation.***

The DR equipment worked immediately for only about half of participants on initial setup. In some cases, the installation of equipment was initially delayed because of the technician's inability to resolve connectivity issues or lack of available existing wireless router port for the connection of the digital gateway. This sometimes required a second visit to the home by another more experienced technician or installation and setup of a provided wireless router. In other cases, with baseboard electric heat, routing of power supply wires required the technician to make wall penetrations next to the load switch. Additionally, space restrictions around some water heaters required locating the sizable gray plastic load switch (box) in a hallway or kitchen wall. Some of these situations did lead to customer perception of wall damage or customer concern regarding the aesthetics of the installation. Almost one-third of participants were dissatisfied with heat pump and thermostat installation. Focus group participants cited this as a possible barrier to the program's future success. One technician indicated that the numerous types of equipment made the installation process very complicated and increased the likelihood of service calls and delays. Participant satisfaction varied greatly across technologies. Additionally, a number of participants expressed the desire that the technicians provide documentation or instruction regarding operation of the equipment at the time of installation, which was not always provided. Unsightly installation of some equipment has the potential to become an even greater issue in a large-scale, permanent program. PSE should be aware that contractors may be viewed as either internal or external to PSE, which can affect customer perceptions of the program and reflect upon the company.

***Finding #7: Most participants were satisfied with customer service, but a number of customers said they found it difficult to contact customer support staff and resolve problems.***

The majority of participants appeared to be satisfied with their customer service experience. However, nearly one-quarter of participants who contacted a service representative were dissatisfied with their experience. It appears that some participants' difficulty with customer service exacerbated frustrations with the equipment. A number of focus group participants who left the program suggested that explanations or apologies from PSE would have changed their decision to drop out. In surveys and focus groups, customers widely expressed a desire for

accessible, effective, and responsive customer service. Participants demonstrated confusion over whom to contact for assistance, and could benefit from a single point of contact with extended operating hours.

## 1.5 Recommendations

This report has allocated recommendations into one of two categories: those pertaining to the results of the impact evaluation and those pertaining to the results of the process evaluation. There is some cross-over between the program recommendations that have come out of the impact and process analyses and the evaluation team suggests that reviewers read all recommendations. Additionally, all recommendations implicitly assume an interest on the part of PSE in developing a residential demand response program in the future and are intended to provide guidance, based on the lessons learned in the pilot.

### 1.5.1 Impact Evaluation Recommendations:

- **Conduct research into the root cause of the minimal DR impacts observed in the pilot from baseboard heaters.** Impacts from this end-use were found to be minimal and are certainly not cost-effective from a system stand-point. If a curtailment procedure cannot be found which more effectively reduces household demand during events, PSE should not attempt to control this end-use.
- **Limit water heater curtailment to morning-only events when a high proportion of a home's hot water is used.** If PSE wishes to call water heater control events in the afternoon, the evaluation team recommends that additional experimentation be undertaken, using data-loggers and home inspections, to assess why the afternoon curtailment of water heaters seems to result in a snapback impact greater than the DR impact.
- **Consider investigating why a disproportionate number of water heaters failed to respond to control events.** PSE should also consider what alternative technologies exist that may offer more reliable end-point control without sacrificing two-way communication.
- **Target water heaters as the least intrusive and most reliable means for achieving winter peak demand curtailments that are acceptable to customers.** Unlike curtailment of space-heating, the curtailment of water heaters during very cold winter mornings passed almost unnoticed by participants while still providing significant demand reductions when curtailed.
- **Consider offering heat pump and electric furnace customers higher incentives, or using a less aggressive cycling strategy to attain a better balance between per-device impacts and customer satisfaction/participation.** Although the largest demand impacts come from the curtailment of heat pumps and electric furnaces, customer discomfort as a result of curtailment could lead to lower participant retention rates.

- **Track non-responsive end-points on an on-going basis.** Following each event the program manager should review the list of non-responsive end-points. Technicians should be dispatched to service devices which have failed to respond to two or more consecutive end-points. The program manager should also review the technicians' reports for any patterns in the distribution of non-responsive end-points.

### 1.5.2 Process Evaluation Recommendations

- **Find improved, more customer-friendly alternatives to program technologies offered to participants.** Many participants expressed dissatisfaction with the programmable thermostat in particular, but also with the Digital Gateway and the website.
- **Work with contractors and equipment providers to determine to what degree equipment can either be camouflaged or else installed out of sight.** A frequent complaint on the part of participants was the aesthetic impact of control device installation. National standards for security and performance of networked devices such as load switches and communicating thermostats and compatible load management software are evolving. Over the next few years a new generation of open source demand response devices and management software will overcome many of the problems experienced during this pilot.
- **Consider reducing the types of equipment controlled to streamline the installation process and improve participant satisfaction with that process.** Technician's responsible for device installation indicated that many of the delays and challenges at the installation stage were due to the number of different types of equipment to be installed.
- **Establish a well-advertised single point of contact with extended office hours and ensure that customer service representatives are well coached so as to be able to provide clear explanations to customers experiencing problems.** Nearly a quarter of participants that contacted a service representative regarding the pilot were dissatisfied with their experience, and in both surveys and focus groups, participants indicated that there was a significant amount of confusion regarding whom they should contact for help.
- **Update existing program materials, such as newsletters, manuals, and the website, to improve customer understanding of demand response. Although participants seemed on the whole to grasp the end purpose of DR (shift usage, defer infrastructure investment), few could explain what it was.** It is especially important for customers to understand that their participation will likely result in few, if any, energy savings and that they are unlikely to observe any noticeable bill savings as a result of participation.

## Section 2. Introduction

The Puget Sound Energy (PSE) Residential Demand Response (DR) Pilot was designed to assess the peak demand reduction achievable through the control of residential space and water heating equipment, and the level of customer acceptance of that control. This report evaluates the demand impacts of the program as well as providing an evaluation of program processes and achievements related to customer recruitment, equipment installation and performance, and customer satisfaction.

### 2.1 *Background on the DR Pilot*

The Bainbridge Island population and electric demand (including a predominance of residential electric space heat) has grown rapidly over a period of more than 20 years since the late 1980s. PSE was in the process of planning electric transmission upgrade projects for the island to address the increasing risk of cold weather overloads on two of three island substations and improve electric system reliability during winter storms. PSE actively engaged in a public process with island residents, interest groups and local officials. In response to stakeholder requests for a demonstration of potential alternatives to substation expansion, PSE offered to conduct a technology-based DR pilot leveraging voluntary customer participation among island customers. The pilot would use broadband communications and in-home control switches to temporarily curtail load from space and water heating appliances.

The pilot design was based on early guidance provided by PSE's outside stakeholders group (Conservation Resources Advisory Group). This guidance was articulated at the time of PSE's original 2007 proposal for funding pilot-scale demand response initiatives under the utility's conservation funding mechanism. The decision to offer the pilot on Bainbridge Island was made in the summer of 2009.

The pilot used a load switch to cycle (off) water heaters, electric baseboard heaters, and forced air furnaces. Water heaters were completely switched off for the full duration of the events, whereas space-heating devices were cycled off for approximately two-thirds of their normal operating time during events. A programmable communicating thermostat was used to cycle heat pumps. Installing the thermostat for a heat pump involved removal of the existing thermostat and reconnecting the existing low voltage control wires to the correct terminals of the replacement communicating thermostat. A low voltage wiring permit issued by Washington State was required for each installation. Load switches were installed to control line voltage loads (typically 240V) associated with electric forced air furnaces, baseboard heaters and electric water heaters. These installations were subject to post-installation inspection by a code official.

A digital gateway was installed in every participating customer's home in order to provide secure two-way communications via the customer's wireless router and the home's broadband Internet connection and the head-end hosted software. Each load switch and/or programmable thermostat was designed to have wireless two-way communication via the gateway.

The demand response software was accessed by PSE to schedule and dispatch curtailment events and restorations. Participating customers were able to access a dedicated website primarily for purposes of programming their thermostats. Customers who wanted to opt out of events for heat pumps could also do this through the web website either before or during an event, and could do so for up to 50% of curtailment events without losing their \$50 incentive payment. Customers with load switches could contact the external implementation team's 1-800 customer service line to request advance opt out for a future event.

## *2.2 Objectives of the Evaluation*

The three over-riding purposes of this evaluation are to:

- Estimate the average demand reduction impact of the devices controlled by PSE.
- Document the level of participant satisfaction with the program.
- Identify barriers to and drivers of participation in the pilot.

Ultimately, this evaluation is intended to provide guidance to program staff wishing to understand the potential for a larger scale demand response program and the challenges that such an implementation would need to surmount. The objectives identified above, and the ways they are addressed within this report are intended to provide program staff with answers to certain key research questions:

1. What is the level of kW reduction provided by each type of device (water heater, heat pump, etc.) during curtailment periods?
2. How should any future larger scale program roll-out be marketed to customers to ensure high levels of participation and participant retention?
3. In what ways can the results of the pilot be improved upon in the context of a large scale program roll-out, so as to optimize aggregate demand impacts and participant satisfaction?



### 2.3 Reported Program Participation

Recruitment for the pilot program began in October of 2009, with most participants enrolled by January of 2010. PSE successfully recruited and retained approximately 530 participants out of a targeted population of approximately 6,700 customers on Bainbridge Island, about 8% of its target population.

Participants could elect to have either just their water heater or their water heater and space-heating equipment controlled by PSE during the pilot. A summary of the devices participating in the program is provided in Table 9, below. The dots in the table indicate the group within which each customer count falls – for example, there were 193 participants that had only a water heater control device installed, 51 that had a water heater and baseboard control device installed, etc.

**Table 9: Summary of Participating Devices**

Water Heater	Heat Pump	Electric Furnace	Baseboard	Number of Participants
•				193
•			•	51
•		•		46
•	•			208
			•	2
		•		3
	•			25
Total Number of Participants:				<b>528</b>

*Source: External implementation team's installation database*

Curtailed impacts were estimated as the average impact per type of device – water heater, heat pump, electric furnace or baseboards – controlled. Prior to this evaluation of the pilot impacts, PSE had not yet reported any empirically estimated demand reduction impacts due to the pilot.

The remainder of this report includes the following:

- **Section 3 – Evaluation Methods** describes the methods used by the evaluation team to estimate the demand response impacts of individual device types and the approach used for the process evaluation.
- **Section 4 – Program Impacts – Winter** provides a detailed analysis of the achieved load reductions for winter events, the potential aggregate impact on Bainbridge Island should

the program be expanded, and the impacts of curtailment on indoor winter temperature for heat pump participants.

- **Section 5 – Program Impacts – Summer** provides an analysis for summer events similar to the winter event analysis.
- **Section 6 – Process Findings** describes the findings synthesized from the outcomes of the in-depth interviews, the responses received in the participant survey, and the results of focus group sessions.
- **Section 7 – Conclusions and Recommendations** summarizes high-level findings and provides recommendations, principally intended to guide program managers interested in implementing a broader residential demand response program in PSE territory.

## Section 3. Evaluation Methods

The evaluation of PSE's Residential DR Pilot was conducted on parallel paths, one estimating program impacts and the other addressing program processes and customer feedback. Consequently, this section of the report is split into two principal sections: first, the data and methods used for the **impact evaluation** and second the methods employed in the primary **process evaluation** research.

### 3.1 *Impact Evaluation Methods and Data*

Demand reduction and snapback impacts were estimated using fixed effects regression analysis applied to participant interval data, weather data and data flags indicating the hours in which events took place. The remainder of this sub-section details the data and the econometric method used in the analysis. Appendix I provides further discussion of the regression model.

#### 3.1.1 **Data Used for Impact Evaluation**

The evaluation team used the following data in estimating the impact of the Pilot:

1. *Meter data for program participants*, indicating consumption (kWh) per household in fifteen minute intervals. Provided by Puget Sound Energy.
2. *Installation and removal data*, indicating the date on which participants had load switches or thermostat controls installed (or removed) and to what device or devices they were connected. Provided by the external implementation team.
3. *Hourly temperature data* for Bainbridge Island. Provided by PSE.
4. *End-point responsive data* for all end-points. In some cases certain end-points (e.g., a given participant's water heater) might not respond to the signal to curtail. End-point response data was used to control for faulty load switches, thermostats and signal problems when estimating impacts. Provided by the ESV.
5. *Indoor temperature data* for participants with controlled heat pumps. Indoor temperature data is generally, although not always, available for the day of an event, the day after and the day before. Provided by PSE.

In total, PSE provided useable meter data for 494 participants. In some cases Automatic Meter Read (AMR) meter data collected was either flagged as unreliable by PSE staff or missing due to technical problems. The data was provided to the evaluation team in quarter-hourly intervals,

and the team aggregated this data up to the hourly level for purposes of analysis and reporting.<sup>2</sup> Table 10 below shows the number of participants for which interval data was available by the type of equipment that was controlled by PSE.

**Table 10: Participants With Interval Data By Device Type**

Water Heater	Heat Pump	Electric Furnace	Baseboard	# Participants w/ Interval Data
•				182
	•			23
		•		0
			•	2
•	•			194
•		•		45
•			•	48
Total # of participants w/ useable interval data:				<b>494</b>

*Source: Navigant Analysis*

### 3.1.2 Econometric Estimation Method

The following discussion describes the method by which the evaluation team estimated the impacts of the various technologies implemented as part of this pilot. Key steps and considerations include:

1. Fixed effects regression modeling by hour and season
2. Improved model specification through sub-sampling by device type
3. Use of additional explanatory variables for baseboard heaters.

Appendix I provides additional detail on the regression model.

#### 1. Fixed Effects Regression Modeling

The evaluation team used an econometric technique known as “fixed effects” regression to estimate the impacts of the various types of device curtailed. Fixed effects regression is a form of linear regression commonly used in estimating the impact of demand response programs. The technique is applied to panel, also known as longitudinal, data—a set of observations of

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<sup>2</sup> In cases where there were fewer than four good consumption entries per hour, hourly consumption was extrapolated based on good consumption entries present. The implicit assumption being that the average level of consumption across the entries present for each hour is the same as the average level of consumption across the missing entries. Hours for which no consumption data was present were dropped from the sample.

some variable of interest (in this case electricity consumption) from a number of different individuals (i.e., program participants) over time. Fixed effects regression assigns each individual participant his or her own dummy variable. In this way, the analyst may control for each individual's time-invariant characteristics such as the size of a participant's home, its orientation, etc.

The evaluation team chose to estimate a different regression equation for each hour of the day in each season (summer and winter), rather than estimating a single equation with dummy variables to control for the time of day. By estimating separate equations for each hour, the implicit assumption is that in addition to consumption being a function of the hour of the day and the interaction between the hour of the day and whether or not that day has a curtailment event it is also a function of the interaction between the hour of the day and temperature, the hour of the day and the fixed effect, etc.

In addition to estimating a different model for each hour of the day, a different model was estimated for each of the two seasons in which curtailment events took place, winter (November, December, January and February) and summer (July and August). This sub-sampling by season was done for much the same reason as the sub-sampling by hour.

## ***2. Improved Model Specification through Sub-sampling by Device Type***

Exploratory analysis of the data by the evaluation team indicated that the type of device used for heating a participant's home was an important determinant of estimated demand impacts, even with the inclusion of the fixed effect term. Further investigation showed that in fact the fixed effect alone was insufficient to capture the interaction between the type of heating equipment and external temperature.

For example, the quantity of electricity consumed by a heat pump on a very cold morning relative to that consumed by the heat pump on a moderately cold morning is very different to the quantity of electricity consumed by an electric furnace on a very cold morning relative to that consumed by the same furnace on a moderately cold morning. In this case, a driving factor for the difference is the dramatic manner with which a heat pump's efficiency changes at very cold temperatures. As outdoor temperatures decrease below a point in the 30 to 40 degree F range, most heat pumps in the PSE service area engage increasing increments of auxiliary electric resistance heat. This additional heat supplements the heat extracted by the outdoor unit from the ambient air in order to maintain the indoor set-point (room) temperature. Among a population of residential heat pumps in PSE's service area, there is typically wide variation in the ability of any individual home's heat pump system and control scheme to optimally minimize both the addition of electric resistance heat and decline in system heating efficiency.

Electric furnaces exhibit consistency in heating efficiency, though, at much lower seasonal heating efficiency than most properly installed heat pumps.

As a consequence of the link between space-heating device type and estimated load impacts, the evaluation team concluded that the most efficient way to control for these interactions was to split participants into four sub-samples, encompassing those with the following controlled devices or combinations of devices:

1. Water heater only
2. Heat pump controls only, or heat pump and water heater controls
3. Electric furnace controls only, or electric furnace and water heater controls
4. Baseboard controls only, or baseboard furnace and water heater controls

For each sub-group a separate set of regressions was run to estimate the impact of controlling the various types of devices.

### Considerations for space heating equipment

The subsets of participants, defined by the principal space-heating equipment, tended to be overwhelmingly composed of participants with both space-heating equipment controls *and* water heater controls. Since all end-points (space-heating and water heating) were controlled simultaneously and because the pilot design did not include the collection device-specific logger data, it is impossible to explicitly separate out the effect of control of one device (the water heater) from the other (space-heating equipment).

Thus, the analysis estimated space heating impacts by estimating the combined impact of space and water heat controls and subtracting out impact of the water heat controls alone. This was possible since there was a sufficient sample of customers with only water heaters controlled. This approach produced reasonable and operationally significant estimates for the impacts of heat pump and electric furnace controls.

### Considerations for baseboard heating

The approach described above did not lead to significant estimated impacts from baseboard heater controls—possibly due to the fact that in homes where baseboard heating was controlled, only a portion, and not all, of the baseboard heaters were curtailed. Thus, it was possible that the reduced consumption of curtailed baseboard heaters was being made up for by non-controlled baseboards within the same house. Consequently, the regression model was modified to control for the proportion of

curtailable baseboard capacity (as provided by the external implementation team responsible for installing the control device) to non-curtailable baseboard capacity within a household (as estimated from maximum annual household load). This proportion was used as an explanatory variable in the equation and allowed the evaluation team to obtain statistically significant impacts for morning winter events.

### ***3.2 Process Evaluation Research Methods***

The process evaluation provided an in-depth understanding of customer and staff experience with the pilot that can be used to help assess whether to offer a large-scale program and, if so, to inform program design and delivery. The ultimate goal of this research was to provide PSE with recommendations for long-term optimization of program value.

The evaluation research was primarily based upon the following three research components:

- In-Depth Interviews with Program and Delivery Staff.
- Telephone Survey of Participants, Past Program Participants (“dropouts”), and Non-Participants
- Focus Groups of Participants and Dropouts

Sample sizes for each of these three research components are provided in Table 11.

**Table 11: Study Methods and Subjects**

Study Method	Subject Groups	Number of Individuals
In-Depth Interviews	<ul style="list-style-type: none"> <li>• 3 PSE Staff</li> <li>• 2 Staff members from the external implementation team</li> <li>• 2 ESV Staff</li> <li>• 1 Electric Staff member from the electrical contractor <i>(Managed by the external implementation team)</i></li> </ul>	8
Telephone Survey	Participants, dropouts, non-participants	143
Focus Groups	Participants, dropouts	14

*Source: Navigant/EMI*

### 3.2.1 In-Depth Interviews

**In-depth interviews** were conducted with: 3 PSE Program Staff, 2 Staff from the external implementation team, 2 ESV Staff and 1 Electric Staff member from the electrical contractor in May of 2011. These individuals held the following roles:

- Outgoing PSE Program Manager
- PSE Manager of New Program Development and Evaluation
- PSE Senior Market Analyst
- ESV Project Manager
- ESV Technical Services Manager
- External implementation team’s VP of the Western Region
- External implementation team’s Field Project Manger
- Electrical contractor’s electric technician *(Managed by the external implementation team)*



The objectives of the in-depth interviews were to gain a more thorough understanding of program processes and to identify specific areas of program delivery where inefficiencies and/or areas in need of improvement may exist. The interviews were primarily intended to provide qualitative information, and the small sample size does not allow adequate statistical precision to make judgments about the representativeness of the samples.

The roles of the organizations are described in Table 12. In addition to providing details of program implementation, program staff members were asked to comment on program successes and challenges. The interview guides, included in Appendix II, were intended to serve as a discussion guide rather than a verbatim survey and were slightly customized for each organization. This format gave the interviewer flexibility to probe for additional information into areas of interest and value.

**Table 12: Interviewee Organizations and Roles**

Organization	Number Interviewed	Roles of Organization
Puget Sound Energy	3	Marketing and recruiting, program oversight and coordination, event scheduling/dispatch and preparation of reports.
External Implementation Team	2	Contributed to the development of initial marketing materials, provided toll-free call center, handled enrollment, set appointments for installation, supplied device registration/installation data collected in the field to the ESV. Conducted field installation training for electrical contractor technicians, and managed field installations, provided troubleshooting and resolution of technical issues encountered by technicians in the field.
Equipment and Software Vendor (ESV)	2	Provided technical consulting to the external implementation team on hardware capabilities and installation practices and recording and supplying the essential registration data for each digital gateway, thermostat and switch in the hosted software. The ESV also provided training to PSE program staff on the software capabilities, event setup/dispatch and reporting processes. The ESV provided all hardware, and operated/maintained the hosted software, which included the participant website.
Electrical Contractor	1	Install/troubleshoot pilot equipment in customer homes, provide service calls, secure electrical installation and low voltage wiring permits.

Source: Navigant/EMI

### 3.2.2 Telephone Survey

The telephone survey was intended to solicit responses from statistically significant samples of participants, dropouts, and non-participants in order to evaluate customer demographics, awareness and knowledge of the program, satisfaction with installation and customer service, motivations to participate, experience with curtailment events, and interaction with technologies. Survey respondents were encouraged to describe their experiences to inform qualitative analysis of program strengths and areas in need of improvement. Demographic data were collected to characterize the participant population relative to the Bainbridge Island community.

#### Survey Sample Design

The survey sampling plan for the evaluation of the Pilot was designed with the goal of attaining 90/10 confidence/precision for each of the three types of customers: participants, past participants who left the program mid-cycle (“dropouts”), and non-participants.<sup>3</sup> Non-participants were selected from PSE’s targeted group of single-family customers. Table 13 presents the sample design by customer type showing the total population, minimum required completes to attain 90/10, evaluation team goals, final number of completed surveys, and resulting margins of error.<sup>4</sup>

**Table 13: Bainbridge Island Demand Response Pilot Program Sample Design**

	Population (N)	Required for 90/10	Goal	Survey Respondents	Margin of Error
<b>Participants</b>	495	60	65	66	9%
<b>Dropouts</b>	28	21	28	7	27%
<b>Non-participants</b>	6171	67	70	70	10%
<b>TOTAL</b>	<b>6694</b>	<b>148</b>	<b>163</b>	<b>143</b>	

Source: Navigant/EMI

Telephone surveys were conducted with 13.3% (n=65) of total participants, 25% (n=7) of dropout participants, and a random selection of 70 non-participants. While 90/10 was exceeded with the participants and non-participants groups, only seven dropouts completed the survey, even after 10 attempts were made to contact each of these customers. As such, the margin of error is

<sup>3</sup> Target sample sizes at a 90/10 confidence/precision assume a binomial distribution (e.g., yes/no questions) and are dependent on the size of the population.

<sup>4</sup> Participants and dropouts who participated in the focus groups were not included in this population.

notably large for the dropout group and any statistical inferences about this group warrant careful interpretation.

### **3.2.3 Focus Groups**

The evaluation team conducted two focus group sessions with a total of 14 customers on Bainbridge Island on June 14, 2011. The first focus group consisted of individuals who were actively participating in the Pilot. The second group consisted of individuals who had initially joined the program and have since ended their participation. The results of these focus groups can be used to inform future demand response program efforts that PSE may pursue, in particular influencing the design and educational components of future programs.

The focus group method allows the researcher to observe group dynamics and understand how opinions are structured in a manner not possible through other primary research methods, such as surveys or in-depth interviews. The evaluation team constructed moderator guides (See appendices below) that were flexible enough to adapt to the group setting and unanticipated topics of discussion, while retaining a focus on the objectives listed above.

The primary objectives common to both focus groups were the following:

1. Determine how participants interpret PSE's marketing materials and efforts.
2. Document participants' motivations for enrolling in the program.
3. Characterize participants' understanding of, and experiences with, the PSE demand response pilot program.
4. Document potential concerns and potential barriers to program success.
5. Identify areas for improvement in the program.

For the focus group of individuals who had initially joined the program and have since ended their participation an additional objective was explored: to document reasons why participants discontinued participation in the program.

### **Participants**

The evaluation team recruited and paid a \$100 incentive to 14 residential customers, including seven men and seven women. The customers were identified through a contact list supplied by PSE of demand response program participants. Participants were then screened and recruited for one of the two focus groups based on their involvement with the program. One group consisted of participants who are still actively involved with the demand response program, while the second group consisted of those participants who had cancelled their involvement

with the program. The screener guide used to select participants is detailed in the appendices below. All but one participant use a heat pump as their primary heating source.

### **Observers**

Representatives from the evaluation team and from PSE were also present and in the same room as the focus group participants. The facility rented for the focus group in Winslow on Bainbridge Island had an open private room that allowed observation and audio/visual recording of the sessions.

### **Limitations**

Focus groups are powerful tools for examining the ways in which people interact and share experiences in the process of exploring perceptions, attitudes, and opinions. Because of their interactive nature, focus groups provide insight that would be difficult, if not impossible, to garner using other methods. At the same time, however, the focus group method also presents certain limitations.

First, it is important to emphasize that the results of focus groups have limited generalizability. Participants are not randomly selected, but are chosen because of certain characteristics they hold in common. In this case, participants were selected because they are either actively involved in the demand response program or because they were initially involved and have since cancelled their participation in the program. The number of participants also limits generalization. For this study, fourteen participants in two groups of seven contributed to the findings. If we consider the size of the actual population of initial participants in the demand response program, a little more than 500 households, it is clear that fourteen subjects are not likely representative of *all* the perceptions, attitudes, and opinions of this population.

Second, it is crucial that the reader keep in mind that the implications of our findings are not statistically based and are drawn from a relatively small, non-random sample. That said several relevant findings are worth noting as they relate to demand response programs that PSE may pursue in the future. It is also important for the reader to understand that the exact number of customers who agree on a specific topic cannot be explicitly defined for many questions because of the dynamic conversational nature of focus groups. In other words, the central topic of the focus group often changes (as the research team expects) before all participants are allowed to respond to any particular question. Thus, this report uses language such as “some,” “many,” or “most” based on general observations from the focus group data.

## Section 4. Winter Program Impacts

This chapter discusses in detail the winter impacts estimated by the evaluation team from the curtailment of the four types of devices that were part of the PSE Residential DR Pilot. Impact findings are presented as follows:

1. Average load reductions by device type (morning and afternoon) for successfully curtailed devices, including potential system impacts on Bainbridge Island should the program be expanded
2. Hourly demand impacts
3. Indoor temperature impacts for heat pump participants

A summary of the dates and times of the curtailment events is presented in Table 14, below. All devices were curtailed for all events.

**Table 14: Summary of Winter Curtailment Events**

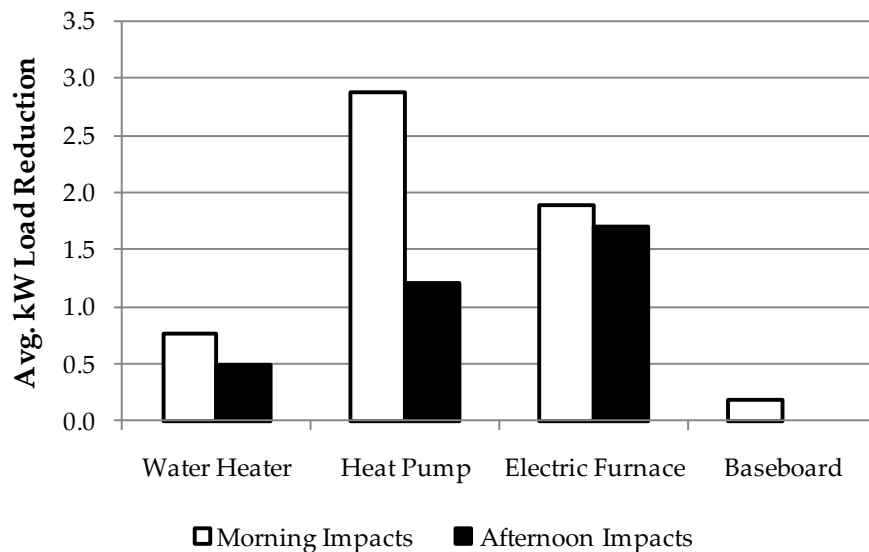
Date	Start Time	End Time
9-Feb-10	7:00	9:00
22-Nov-10	6:00	9:00
10-Jan-11	6:00	9:00
10-Jan-11	16:00	19:00
11-Jan-11	6:00	9:00
11-Jan-11	16:00	19:00
2-Feb-11	6:00	9:00
24-Feb-11	6:00	9:00
25-Feb-11	6:00	9:00

### 4.1 Load Reductions by Device Type

Curtailment impacts were estimated for each type of device and for each hour. Hourly impacts were then averaged across morning and afternoon curtailment events for presentation purposes. As may be seen in Figure 6 and Table 15, on a device-by-device basis, the greatest demand impact was made by heat pump curtailment in the morning, followed by electric furnace curtailment in both the morning and the afternoon. Baseboard heater impacts were found to be very small in the morning and non-existent for afternoon events.

The estimated impacts shown below are the average per-device impact of a successfully controlled device. A successfully controlled device in this case is defined as a device (or end-point) that the implementation contractor was able to verify actually responded to the curtailment signal. The overall percentage of successfully controlled devices (i.e., devices which received the signal to modify operation) ranged from 57% for water heaters to 75% for baseboard heaters, as shown on the bottom row of Table 15. The majority of non-responsive end-points were non-responsive to all of the events called.

**Figure 6: Average Impact per Successfully Controlled Device – Winter (Chart)**



Note: Impacts in this chart and the charts and tables which follow are averages across successfully controlled devices unless otherwise noted in the text.

Source: Navigant analysis

**Table 15: Average Impact per Successfully Controlled Device – Winter (Table)**

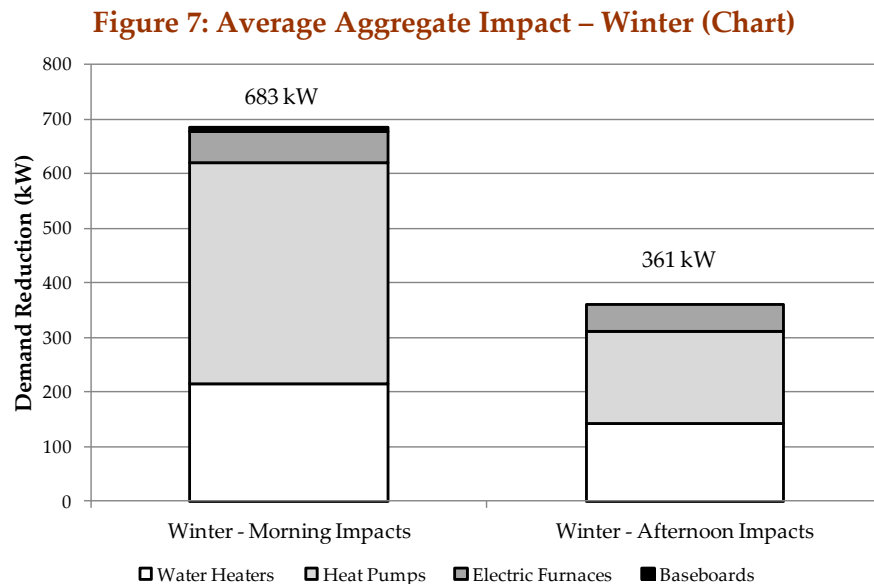
	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards
Morning (kW)	0.77	2.88	1.88	0.18
Afternoon (kW)	0.48	1.21	1.71	0.00
Average % of Devices Successfully Curtailed	57%	64%	64%	75%

Source: Navigant analysis

When estimated impacts are shown in tabular format below, in some cases cells contain “N/A” rather than a numeric estimate. In these cases, the estimated impact is not statistically

significant at the 90% level. This means that it is impossible to be sure, with 90% confidence, that the estimated impact is not just the result of random variation in the data rather than the impact of the experimental treatment. In most cases the evaluation team treats these estimates by conservatively assuming that since no impact can be confirmed to be statistically significant, no impact exists.

**The average aggregate impact that the pilot had on Bainbridge Island load for winter morning and winter afternoon events, split up by type device curtailed, may be observed below in Figure 7.** Note that while an electric furnace’s individual average demand savings are very high, electric furnaces account for fewer than 10% of the controlled devices, resulting in a relatively small aggregate average impact.



The precise figures making up Figure 7, as well as the average percent of load switches that responded to the control signal are shown in Table 16 and Table 17 below. Note that there is a considerable difference between the aggregate impact in the morning and the afternoon of both water heaters and heat pumps. Water heater curtailment yields a much greater impact in the morning due to hot water use typically being greater in the morning than in the afternoon (showering). Heat pump curtailment yields a much greater impact in the morning due to the fact that that on very cold winter mornings the heat pump must engage its (very inefficient) auxiliary resistance heat strips in order to supply the heating load. This auxiliary heat is considerably less efficient than the standard heat pump operating mode (which is what is used to heat the house in the afternoon, when it is warmer). Thus curtailment impact in the morning is really the impact of curtailing electric resistance heat, whereas the curtailment impact in the



afternoon is the impact of curtailing a (much more efficient) heat pump. Further discussion of these two findings may be found below in 1.3 and Section 4.

**Table 16: Average Aggregate Impact – Winter Mornings (Table)**

	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards	Total
Average Aggregate Impact (kW)	215	404	57	7	<b>683</b>
Average # of Participating Devices	478	219	47	53	
Average # of Devices Successfully Curtailed	272	140	30	40	
Average % of Devices Successfully Curtailed	57%	64%	64%	76%	

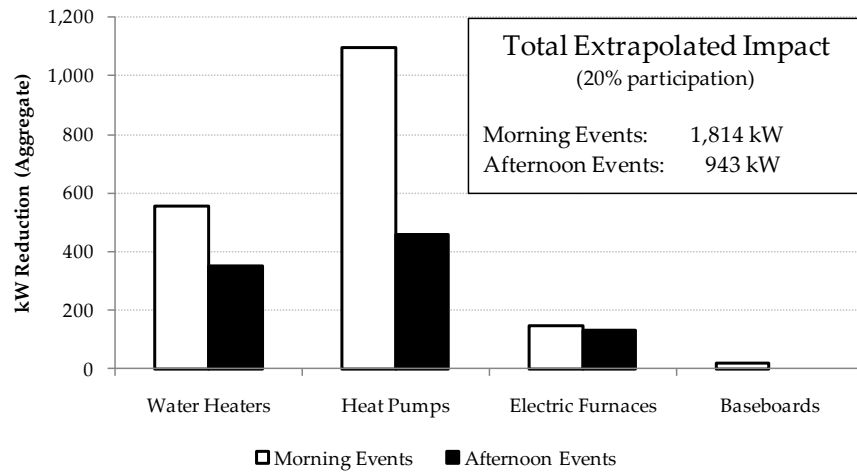
**Table 17: Average Aggregate Impact – Winter Afternoons (Table)**

	Water Heaters	Heat Pumps	Electric Furnaces	Baseboards	Total
Average Aggregate Impact (kW)	141	171	50	0	<b>361</b>
Average # of Participating Devices	480	218	47	53	
Average # of Devices Successfully Curtailed	291	141	29	40	
Average % of Devices Successfully Curtailed	61%	65%	62%	75%	

**Potential Aggregate Impacts on Bainbridge Island.** One of the objectives of the pilot was to estimate the potential impact that would result from the wider deployment of such technologies on Bainbridge Island. Accordingly, the evaluation team extrapolated the aggregate demand impacts for winter events if PSE were to be successful in recruiting 20% of its approximately 6,700 Bainbridge Island customers to participate in a residential DR program. These extrapolated aggregate impacts assume that the distribution of devices would be identical to that of the pilot, that the same percentage of end-points would be successfully curtailed as in the pilot, and that the pilot participants are representative of the broader Bainbridge Island

population. Under these assumptions, a winter program could be expected to provide nearly 2 MW of curtailments in the mornings and nearly 1 MW in the afternoons.

**Figure 8: Extrapolated Aggregate Impact by Device Assuming 20% Participation - Winter**



Source: Navigant analysis and ESV End-Point Data

Observations from the evaluation team and additional detail of findings by device type are presented below:

#### Water Heaters

- At the individual household level, control of water heaters provides a relatively modest amount of demand response. However, these appliances account for perhaps the greatest potential for more widespread implementation, given the number of electric water heaters on Bainbridge Island, and it appears that very few participants were inconvenienced or even noticed it.
- The demand response potential of water heaters is greatest in the morning when hot water demand for showers is highest. Curtailment of this device in the afternoon (when fewer participants tend to be at home using hot water) yields only modest savings compared with morning curtailment, as illustrated in Figure 6, above.
- Water heaters curtailed in the afternoon exhibit snapback impacts that are actually greater in magnitude than the curtailment impacts. This result may be due to the fact that water heaters are typically used relatively little during the three afternoon hours when the events were called (and thus there is little opportunity for load reductions), and the post-event recovery is concentrated in the single hour after the event is over.

## *Heat Pumps*

- Heat pumps have enormous DR potential for a winter-peaking utility because on very cold mornings they often engage their auxiliary (usually relatively inefficient) resistance heating to supply a home's heating.

## *Electric Furnaces*

- Of all the devices curtailed, electric furnaces provided the most consistent demand response impacts, both in terms of reduced demand and the magnitude of snapback.

## *Baseboards*

- Baseboards (and fan- equipped room electric wall heaters) controlled by PSE contributed relatively little load reduction. One possible explanation is that the main reason for baseboards' minimal demand impact is that not all baseboards in a participating home were connected to the control device and that curtailment of some just led to higher levels of consumption in others, thereby negating most of the demand reductions.

## **4.2 Hourly Demand Impacts**

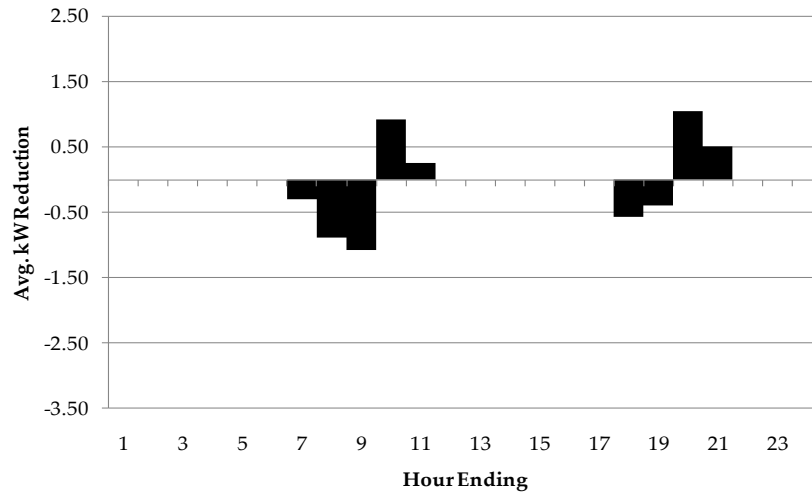
The section below provides hourly detail on device level demand reduction and snapback impacts.

### **4.2.1 Water Heater Curtailment**

The average impact of successful water heater curtailment during the winter is presented graphically and in a tabular format in Figure 9 and Table 18 below. As can clearly be seen in the figure, water heater curtailment had a significantly greater demand reduction impact for morning events than for afternoon events. The most likely reason for this is simply that hot water demand from showers—often the single largest contributor to water heating electricity consumption – is highest in the morning. The fact that the largest morning impact occurs in the final hour of the curtailment period suggests that demand reduction lags slightly behind when the water is used. It seems unlikely that most participants would shower as late as between 8a.m. and 9a.m. (hour ending 9).

Readers should note that in Figure 9 and Table 18 below, negative impacts represent demand reductions due to successful curtailment and that the positive values which follow them represent the estimated snapback impact that occurs after a curtailment event.

**Figure 9: Average Impact per Successfully Curtailed Water Heater**



Source: Navigant analysis

**Table 18: Average Impact per Successfully Curtailed Water Heater**

Morning (Avg kW Impact)						Afternoon/Evening (Avg kW Impact)					
6am - 7am	7am - 8am	8am - 9am	9am - 10am	10am - 11am	11am - Noon	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-0.30	-0.89	-1.08	0.91	0.26	N/A	N/A	-0.57	-0.40	1.05	0.50	N/A

N/A = No statistically significant impact at 90% confidence level.

Source: Navigant analysis

Note that no statistically significant demand reduction was observed to occur, on average, in the first hour of the afternoon curtailment period.<sup>5</sup> This is likely due to the fact that most people do not arrive home from work (and thus start using hot water) until after 5 p.m. The most interesting feature of the estimated impacts of curtailment during the afternoon is that it appears as though the statistically significant snapback impact is actually *greater* than the demand reduction impact. Although counter-intuitive, a reasonable explanation is that even

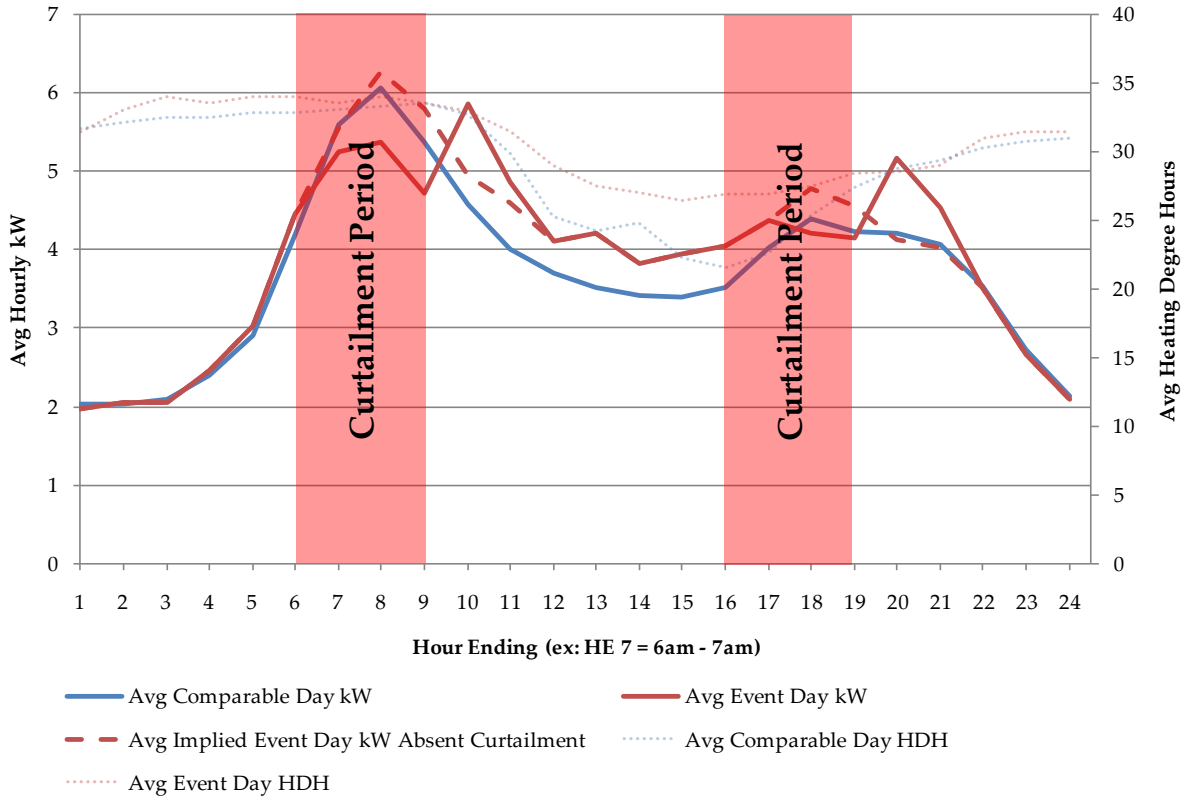
<sup>5</sup> When estimated impacts are shown in tabular format, in some cases cells contain “N/A” rather than a numeric estimate. In these cases, the estimated impact is not statistically significant at the 90% level. This means that it is impossible to be sure, with 90% confidence, that the estimated impact is not just the result of random variation in the data rather than the impact of the experimental treatment. In most cases the evaluation team treats these estimates by conservatively assuming that since no impact can be confirmed to be statistically significant, no impact exists.

when hot water is not being used, water heaters will suffer from modest stand-by losses in order to maintain the water set-point temperature. These stand-by losses tend to be quite small, and not coincident across households. Thus, given the sample size, the demand reduction impact of curtailment on stand-by losses may be statistically undetectable. However, all that standby consumption is not averted, but is shifted to the snapback period when the hot water tank is re-activated. That is, the stand-by consumption that would otherwise have been spread evenly over three hours is aggregated into a single hour, resulting in a statistically significant snapback impact that exceeds the estimated reduction in electricity consumption.

As a test of the reasonableness of the estimated impacts, the evaluation team compared actual consumption on event days with a morning and afternoon curtailment event with the consumption that the parameter estimates imply would have occurred absent curtailment *and* with the consumption of the same households on days of comparable temperature. This graphic comparison is shown in Figure 10. Comparable day consumption is the average consumption of water heater participants during winter weekdays on days in which there were between 650 and 850 heating degree hours (event days had an average of approximately 760 heating degree hours each).

Note that when making the visual comparison between the comparable day consumption and event day consumption that event days tended to be cooler, on average, than the comparable days all through mid-day and, to a lesser extent, during the afternoon curtailment period. This results in an implied consumption absent curtailment which is higher than on comparable days, but which is a very similar shape. Heating degree hours are plotted as pale dotted lines and should be examined when considering the impacts plotted below.

**Figure 10: Winter Water Heater Curtailment – Reasonableness Test**



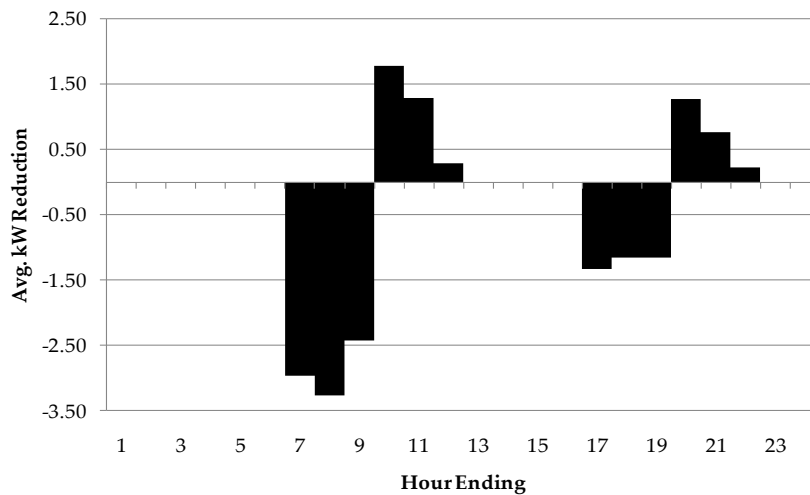
Source: Navigant analysis

### 4.2.2 Heat Pumps

Of all of the devices curtailed, the heat pump curtailment provided the largest average per-participant impact (See Figure 11 and Table 19 below for the average impact of a successful winter heat pump curtailment). The high level of demand reduction observed in the morning curtailment period is likely due to the fact that when it is very cold, heat pumps must rely on auxiliary electric resistance heat rather than operating in their standard efficient fashion. Note that by contrast, the afternoon curtailment events result in a demand reduction of less than half that observed in the morning.

Readers should note that in Figure 11 and Table 18 below, negative impacts represent demand reductions due to successful curtailment and that the positive values which follow them represent the estimated snapback impact that occurs after a curtailment event.

**Figure 11: Average Impact per Successfully Curtailed Heat Pump**



Source: Navigant analysis

**Table 19: Average Impact per Successfully Curtailed Heat Pump**

Morning (Avg kW Impact)						Afternoon/Evening (Avg kW Impact)					
6am - 7am	7am - 8am	8am - 9am	9am - 10am	10am - 11am	11am - Noon	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-2.96	-3.26	-2.43	1.78	1.29	0.28	-1.32	-1.15	-1.15	1.27	0.76	0.23

N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

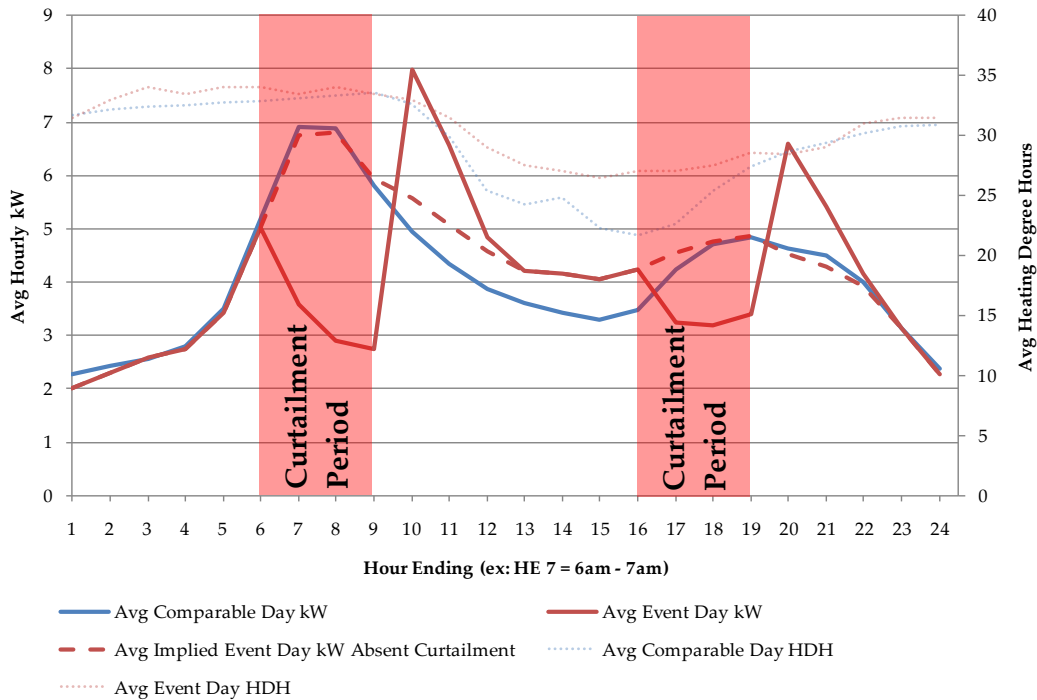
Interestingly, although the afternoon (evening) snapback is less than that of the morning snapback, it is nearly as large as the afternoon load reduction (whereas the morning snapback is considerably less than the morning load reduction). This may be due to customers lowering temperature set points either manually or through the use of programmable thermostats once they leave the home for work at the beginning of the day. Thus the set-point to which the heat pumps must restore household temperature will be lower in the morning (when many participants are not at home) than in the evening (when many participants are in the home). The end result is a very modest snapback in the morning, compared with that observed in the evening.

As above, a comparison of event-day consumption to comparable day consumption is useful for testing the reasonableness of the estimated impacts. Note that the impacts shown in Figure 12 include both the heat pump impact and the water heater impact, although the average water heater impact included in the chart below is lower than that shown above as not all heat pump participants also have water heater controls installed.

As with the water heater reasonableness chart shown above, note that on average the comparable days, while very similar in temperature during the morning peak, deviate somewhat from one another in the mid-day period, with the comparable days being on average, a few degrees warmer. This means that we should expect that load on comparable days in the middle of the day will be lower than the middle of the day load on the event days, and indeed this is what we observe. The higher mid-day load on event days is simply a result of weather and not a result of curtailment. Note the arresting proximity of the implied event-day consumption absent curtailment (dashed red line) to the comparable day consumption (blue line).



**Figure 12: Winter Heat Pump Curtailment – Reasonableness Test**



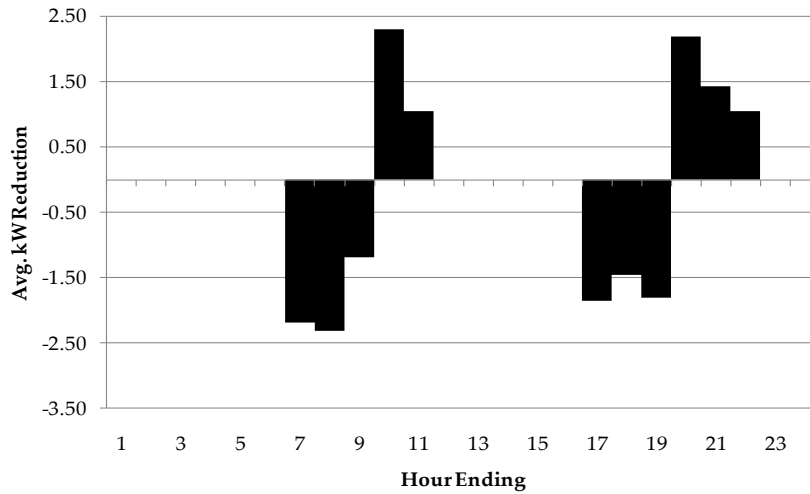
Source: Navigant analysis

### 4.2.3 Electric Furnaces

The demand reduction impact of electric furnaces in the morning, though substantial, is not as great as the impact of heat pump curtailment, as may be seen in Figure 13 and Table 20, below. As noted earlier, the large demand reduction observed in the mornings for heat pumps is likely due to the relative inefficiency of heat pumps during very cold periods when auxiliary resistance heat is required. Since the electric furnace’s efficiency varies less with temperature than does a heat pumps, demand reduction impacts are much more consistent between morning and afternoon. As discussed previously for heat pumps, afternoon snapback is more substantial and longer-lasting in the afternoon than in the morning, relative to demand reduction. This is likely due to a lower set-point temperature being programmed for the hours in which most participants are not home (i.e., late morning).

Readers should note that in Figure 13 and Table 20 below, negative impacts represent demand reductions due to successful curtailment and that the positive values which follow them represent the estimated snapback impact that occurs after a curtailment event.

**Figure 13: Average Impact per Successfully Curtailed Electric Furnace**



Source: Navigant analysis

**Table 20: Average Impact per Successfully Curtailed Electric Furnace**

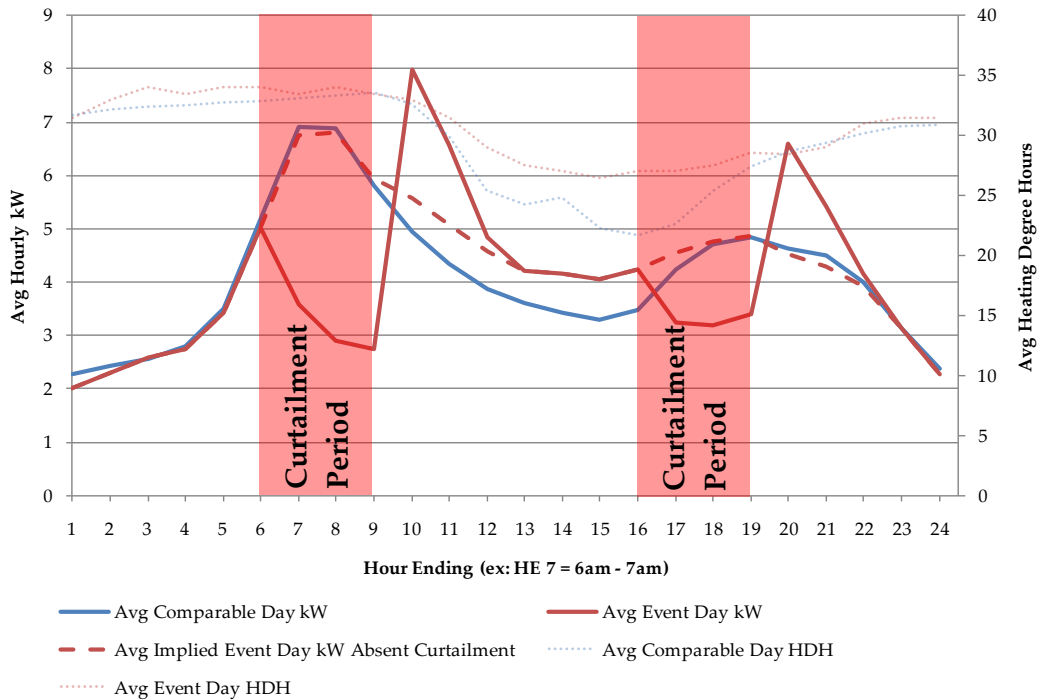
Morning (Avg kW Impact)						Afternoon/Evening (Avg kW Impact)					
6am - 7am	7am - 8am	8am - 9am	9am - 10am	10am - 11am	11am - Noon	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-2.19	-2.31	-1.19	2.29	1.04	N/A	-1.85	-1.47	-1.81	2.19	1.43	1.04

N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

The reasonableness of the accuracy of the estimates obtained of the demand reduction and snapback impacts may be judged qualitatively by comparing event day consumption, implied event day consumption absent curtailment and comparable day consumption to one another, as shown in Figure 14. As with the reasonableness data plot shown above for heat pump participants, note that the implied demand reduction and snapback impacts in Figure 14 reflect the combined average impact of both electric furnace curtailment and water heater curtailment. As previously, note that event day temperatures were, on average, cooler than comparable day temperatures during the middle of the day.

**Figure 14: Winter Electric Furnace Curtailment – Reasonableness Test**



Source: Navigant analysis

#### 4.2.4 Baseboard Heating

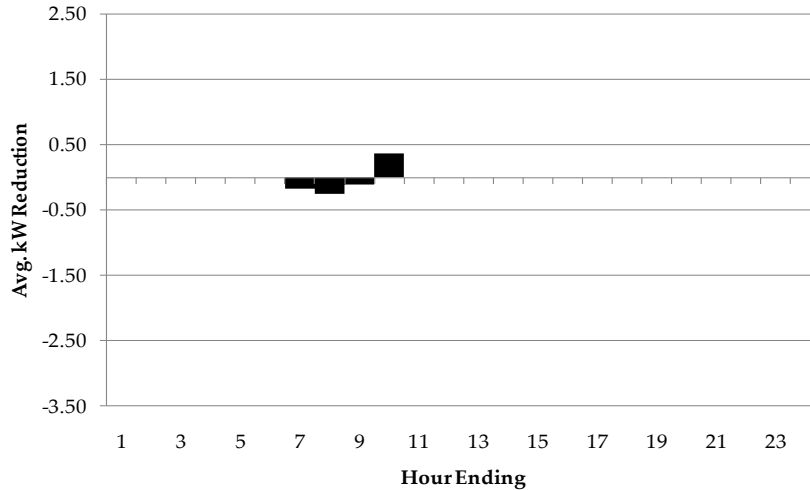
Both demand reduction and snapback impacts of baseboard heater curtailment in the morning are small. In the afternoon, no statistically or practically significant impacts were found, as may be observed in Figure 15 and Table 21 below. There are a number of reasons why the impacts are so low.

First, as mentioned above, participating households did not have all operational baseboards connected to a control device. What this means is that un-connected baseboards will work harder to maintain set-point temperature and thus “take back” most of the demand reduction due to curtailment.

Second, although control device installers were instructed to attempt to connect baseboard units in frequently occupied spaces where curtailment would maximize demand reduction, participants could choose to have less optimally placed units connected. It could be that many participants, out of concern for their comfort during events, instructed the installers to connect only infrequently-used baseboard units to the control device.

Readers should note that in Figure 15 and Table 21 below, negative impacts represent demand reductions due to successful curtailment and that the positive values which follow them represent the estimated snapback impact that occurs after a curtailment event.

**Figure 15: Average Impact per Successfully Curtailed Baseboard Heating Household**



Note: Afternoon impacts were small and not statistically significant  
 Source: Navigant analysis

**Table 21: Average Impact per Successfully Curtailed Baseboard Heating Household**

Morning (Avg kW Impact)						Afternoon/Evening (Avg kW Impact)					
6am - 7am	7am - 8am	8am - 9am	9am - 10am	10am - 11am	11am - Noon	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-0.18	-0.25	-0.11	0.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

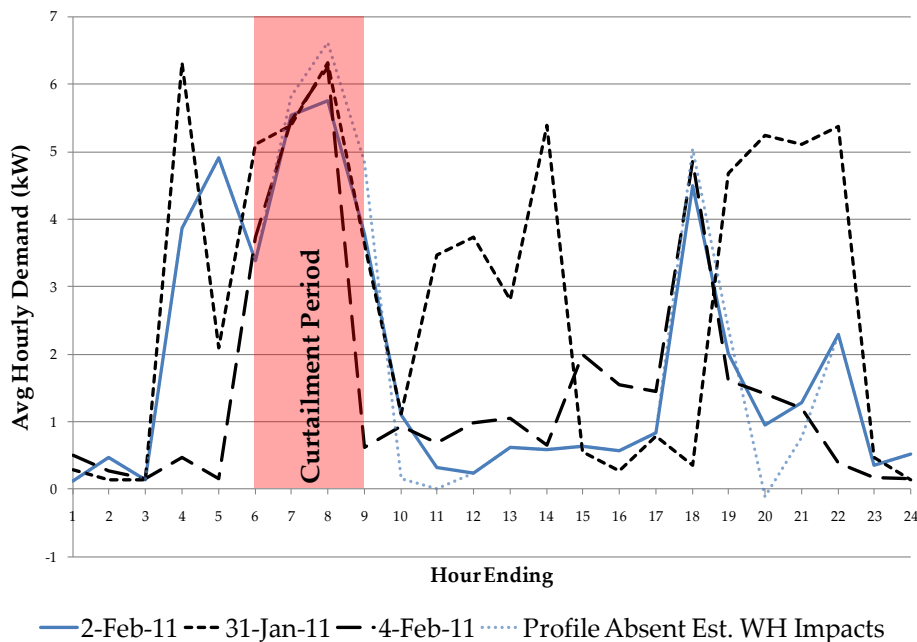
N/A = No statistically significant impact at 90% confidence level  
 Source: Navigant analysis

After initial exploratory regressions provided estimates that were non-significant, the evaluation team proceeded with a thorough investigation of individual load profiles to attempt to understand why impacts were so small. After an extensive review of individual load profiles, it became apparent that in many cases there appeared to be no demand reduction or snapback impact due to baseboard heater curtailment.

Furthermore, while there was some correlation between the magnitude of the impact and the percentage of total heating capacity connected to a control device, the relationship was not consistent across customers.

As an example, consider Figure 16, below, for a participant that elected to have both baseboard heat and water heater controlled by PSE. The light blue line is a plot of this participant’s consumption on February 2<sup>nd</sup>, 2011, a day in which only a morning event was called. The dotted blue line is the implied consumption absent the impact of water heater curtailment. The two dashed lines are the same customer’s consumption on non-event weekdays occurring just before and just after the event day. This customer had one of the highest amounts of baseboard capacity connected to a control device – 12 kW. The highest level of consumption observed during the morning hours for this customer was just under 12 kW. This suggests that a relatively high proportion of baseboard heating installed in this participant’s home was controlled, and yet there is no apparent effect of the curtailment event, other than that of the water heater curtailment.

**Figure 16: Example Individual Baseboard Participant Event Load Profile**



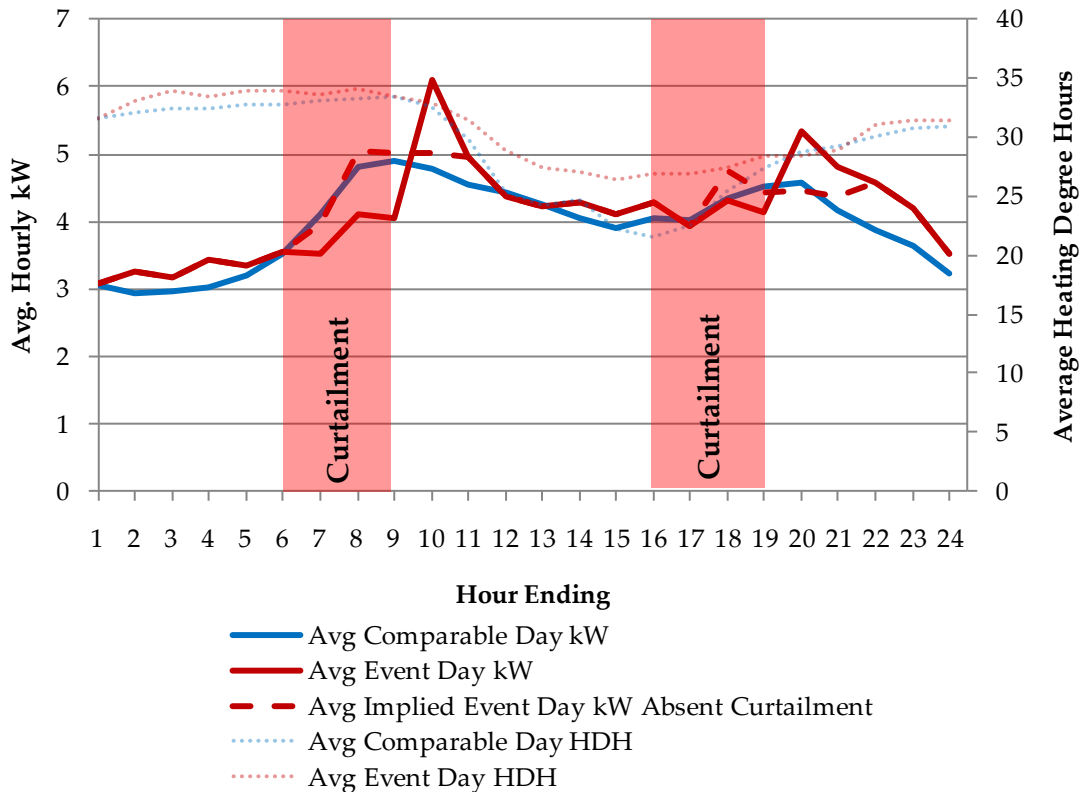
Source: Navigant analysis

There are a number of possible explanations in this case; it could be that this participant elected to have only infrequently used baseboard units connected to the control device or that this participant makes use of portable plug-in space heaters in addition to his or her baseboard units and that these devices compensated for curtailment. The evaluation team also understands that in some cases when the algorithm used for curtailing baseboard units isn’t adaptive to individual unit duty cycles, then the curtailment cycling strategy may not be coincident with the baseboard duty cycle. This would result in the baseboard unit being curtailed when it

would not be generating a significant load. This is likely not the cause of the lack of impact in this case, as an adaptive algorithm was used for the baseboard heaters.

Regardless of the reason why, it appears as though baseboard curtailment had little or no impact on participants' consumption. Presented in Figure 17 below is a plot of average participant consumption on morning and afternoon event days, the implied consumption absent curtailment and the consumption on comparable weather days. Note that the dashed red line – indicating implied consumption absent curtailment - includes the demand from both baseboards and water heaters. This is why there is some apparent demand reduction due to curtailment in the afternoon. This demand reduction comes entirely from water heater curtailment.

**Figure 17: Winter Baseboard Heater Curtailment – Reasonableness Test**



Source: Navigant analysis

### 4.3 Indoor Temperature During Curtailment Events

According to survey responses, a significant proportion of heat pump participants were uncomfortable during the winter events<sup>6</sup>. As a result, PSE asked the evaluation team to investigate what impact winter curtailment had on indoor temperature.

PSE’s hardware and hosted demand response management software (operated by the ESV), tracked indoor temperatures (via the thermostat) for heat pump participants and provided the evaluation team with quarter-hourly temperature readings for all heat pump participants for each event and for the day preceding and following each event<sup>7</sup>.

<sup>6</sup> All of the participants that could recall being home during a summer event reported that they were somewhat or very comfortable.

<sup>7</sup> In some cases prior or following event day indoor temperature data was available only for part of the day.

There were two distinct types of events called in the winter months – morning only events (typically between 6a.m. and 9a.m.<sup>8</sup>) and morning and afternoon events (6a.m. to 9a.m. and 4p.m. to 7p.m.). The average indoor temperatures for these events and for non-event days for which indoor temperature data exist are shown in Figure 18 and Table 22 and Table 23 below.

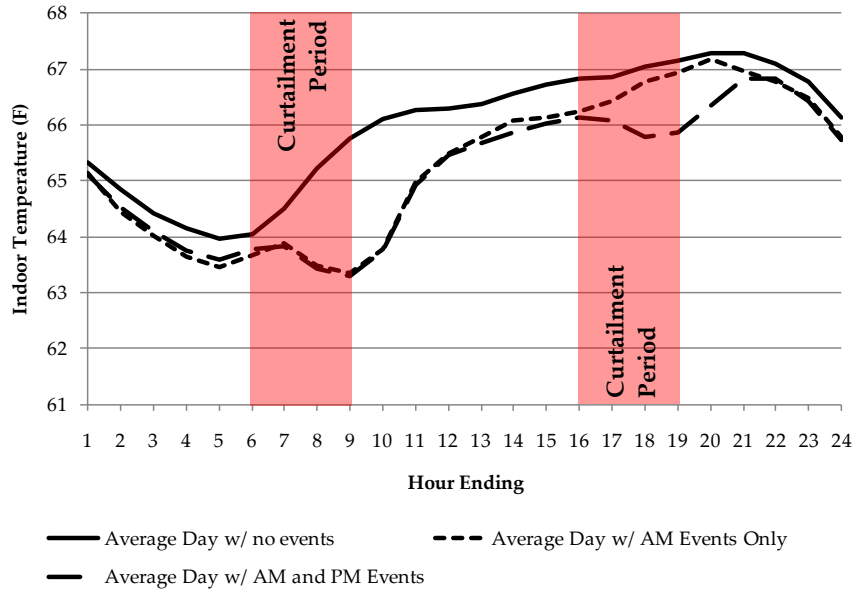
As can be seen from Figure 18 and Table 22 and Table 23 in the mornings particularly there could be a substantial difference between the indoor temperature of a home on event days and on non-event days – sometimes as much as three degrees Fahrenheit. It should be noted, however, that curtailment was not the only driver of indoor temperature. Events were called on very cold days and therefore it is to be expected that the inside of a home will be slightly chillier when it is colder outside. It can clearly be seen in Figure 18, below, that indoor temperatures in heat pump participant homes were lower on event days than on non-event days even during the hours prior to the event being called.

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<sup>8</sup> For clarity, the 7a.m. to 9a.m. winter event is not included in the figures for this section.



**Figure 18: Average Indoor Temperatures by Day Type**



Source: Navigant analysis, ESV data

**Table 22: Average Indoor Temperatures 6a.m. – 3p.m.**

Time Period	6a.m. - 7a.m.	7a.m. - 8a.m.	8a.m. - 9a.m.	9a.m. - 10 a.m.	10 a.m. - 11 a.m.	11 a.m. - Noon	Noon - 1p.m.	1p.m. - 2p.m.	2p.m. - 3p.m.
Hour Ending	7	8	9	10	11	12	13	14	15
Average Day w/ no events	64.5	65.2	65.7	66.1	66.3	66.3	66.4	66.6	66.7
Average Day w/ AM Events Only	63.9	63.5	63.4	63.8	65.0	65.5	65.8	66.1	66.1
Average Day w/ AM and PM Events	63.8	63.4	63.3	63.8	64.9	65.5	65.7	65.9	66.0

Source: Navigant analysis, ESV data

**Table 23: Average Indoor Temperatures 3p.m. – Midnight**

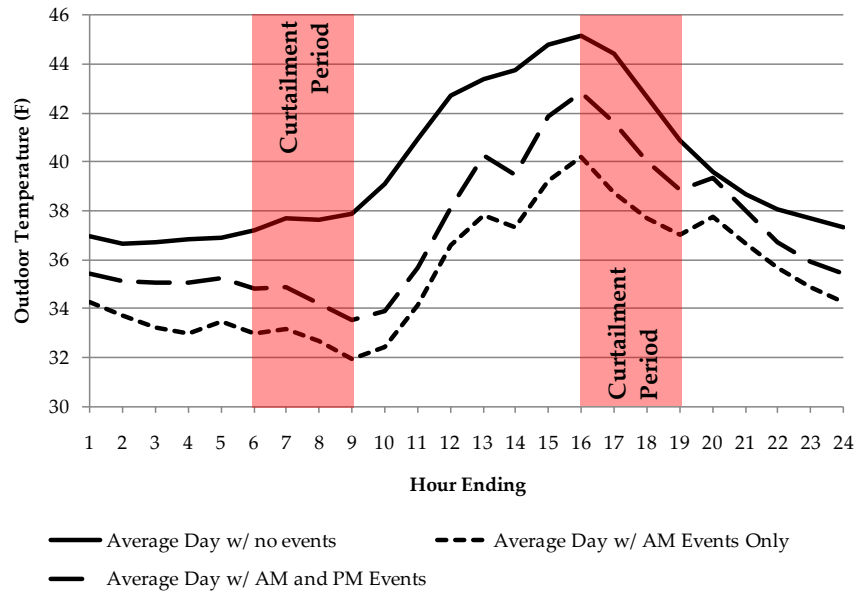
Time Period	3p.m. - 4p.m.	4p.m. - 5p.m.	5p.m. - 6p.m.	6p.m. - 7p.m.	7p.m. - 8p.m.	8p.m. - 9p.m.	9p.m. - 10p.m.	10p.m. - 11p.m.	11p.m. - Midnight
Hour Ending	16	17	18	19	20	21	22	23	24
Average Day w/ no events	66.8	66.9	67.0	67.2	67.3	67.3	67.1	66.8	66.1
Average Day w/ AM Events Only	66.2	66.4	66.8	66.9	67.2	67.0	66.8	66.5	65.8
Average Day w/ AM and PM Events	66.1	66.1	65.8	65.9	66.3	66.8	66.8	66.4	65.7

*Source: Navigant analysis, ESV data*

It is also instructive to examine a plot of average outdoor temperatures on these days to better understand the degree to which they affect indoor temperature and thus participant comfort. Outdoor temperatures on non-event days, morning-only event days and morning and afternoon event days are shown below in Figure 19.

Note that the average outdoor temperature between 8a.m. and 9a.m. (hour ending 9) on the average day with morning events only was about four degrees cooler than on the non-event days for which indoor temperature data were available. This difference in outdoor temperature was a significant driver of indoor temperature as well as the presence of a curtailment event. Of course, in terms of participant satisfaction, it is in some sense academic as to how much of the lower indoor temperatures were caused by curtailment and how much by very low outdoor temperatures – a participant will only know that during an event he or she is uncomfortable.

**Figure 19: Average Outdoor Temperatures by Day Type**



Source: Navigant analysis, NOAA

Nonetheless, it may be instructive for future implementations of demand response technologies for PSE staff to understand the incremental impact on the temperatures in participants’ homes that is due to heat pump curtailment. To estimate the impact of the heat pump curtailment and properly control for the colder exterior temperatures, the evaluation team proceeded as it did for estimating the impact of the curtailment events on electricity consumption – using a series of hourly fixed effects regressions.

These hourly temperature impacts by type of event day (morning only or morning and afternoon) are shown in Table 24 and Table 25, below. As may be seen in the tables below, the largest drop in indoor temperature due the curtailment event occurred in the first hour following the end of the curtailment period – hour ending 10 (9a.m. – 10a.m.). This suggests that participants most likely to be uncomfortably cold during events are those still at home at this time – something which PSE may wish to bear in mind when recruiting participants for some larger program deployment.

**Table 24: Change in Indoor Temperature Attributable to Curtailment 6a.m. – 3p.m.**

Time Period	6a.m. - 7a.m.	7a.m. - 8a.m.	8a.m. - 9a.m.	9a.m. - 10 a.m.	10 a.m. - 11 a.m.	11 a.m. - Noon	Noon - 1p.m.	1p.m. - 2p.m.	2p.m. - 3p.m.
Hour Ending	7	8	9	10	11	12	13	14	15
Delta Temp Due To Curtailment - AM Events Only	-0.26	-1.12	-1.80	-1.81	-0.85	-0.34	-0.24	-0.16	-0.30
Delta Temp Due To Curtailment - AM and PM Events	-0.26	-1.13	-1.76	-1.78	-0.84	-0.35	-0.24	-0.17	-0.30

Source: Navigant analysis, ESV data

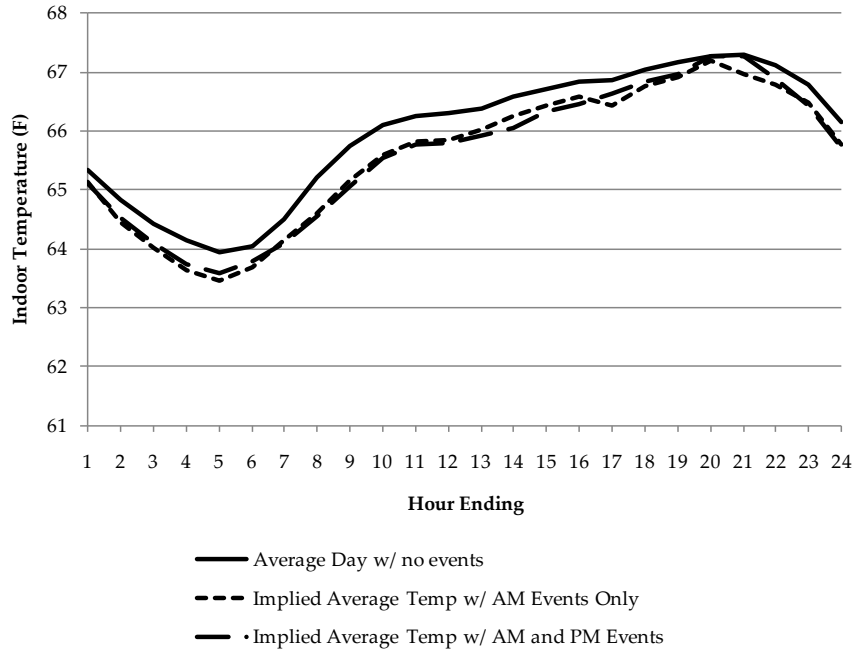
**Table 25: Change in Indoor Temperature Attributable to Curtailment 3p.m. – Midnight**

Time Period	3p.m. - 4p.m.	4p.m. - 5p.m.	5p.m. - 6p.m.	6p.m. - 7p.m.	7p.m. - 8p.m.	8p.m. - 9p.m.	9p.m. - 10p.m.	10p.m. - 11p.m.	11p.m. - Midnight
Hour Ending	16	17	18	19	20	21	22	23	24
Delta Temp Due To Curtailment - AM Events Only	-0.35	0	0	0	0	0	0	0	0
Delta Temp Due To Curtailment - AM and PM Events	-0.34	-0.54	-1.07	-1.10	-0.92	-0.42	-0.08	0	0

Source: Navigant analysis, ESV data

As with the estimated demand impacts, the reasonableness of the estimated temperature impacts may be tested qualitatively by using the values in the tables above to extrapolate the average hourly indoor temperature absent the effects of curtailment and plotting them on the same chart as indoor temperatures on non-event days. As may be seen in Figure 20, below, the shape of the extrapolated indoor temperature curves absent curtailment is very similar to that of average indoor temperatures on non-event days. This is a good indication that the temperature impacts estimated above are reasonable and accurate.

**Figure 20: Average Hourly Indoor Temperatures Absent the Impact of Curtailment Events**



Source: Navigant analysis, ESV data

## Section 5. Summer Program Impacts

With relatively cool summers and limited air conditioning use, the Bainbridge substations do not experience high loading that occurs during cold weather. Summer events in this pilot were added to gain experience potentially useful in the future for relief of hot weather transmission and distribution loading that can occur locally in other parts of the PSE service area. This chapter presents the estimated demand impacts of the summer curtailment events, which were called only in 2010<sup>9</sup> and only for heat pumps and water heaters.

A summary of the dates and times of the curtailment events, and the devices curtailed during each event is presented in Table 26, below.

**Table 26: Summary of Summer Curtailment Events**

Date	Start Time	End Time	Water Heater	Heat Pump
7-Jul-10	15:00	18:00	•	
8-Jul-10	15:00	18:00	•	•
26-Jul-10	16:00	19:00	•	•
13-Aug-10	16:00	19:00	•	
16-Aug-10	16:00	19:00	•	•

There were two types of events called – those running from 3p.m. to 6p.m. and those running from 4p.m. to 7p.m. Impacts from these two types of events were estimated separately for two reasons:

The evaluation team took this approach for two reasons:

1. To explicitly assess the difference in impacts between the two event windows called, and
2. To control for the effects of the “cross-over hour” of 6p.m. to 7p.m. – during the 3p.m. to 6p.m. events, this was a snapback hour, whereas during the 4p.m. – 7p.m. events this was a curtailment hour.

This chapter is divided into two principal sections, presenting the following:

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<sup>9</sup> No pilot events were called during the summer of 2011 because the ambient temperatures never exceed the 85 F threshold temperature. This threshold was chosen to ensure that a reasonable proportion of heat pumps would be operating in cooling mode when an event was called.

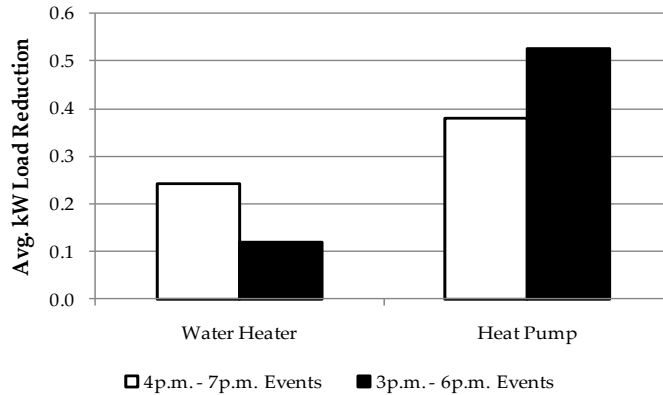


1. Estimated impacts for events called between 3p.m. and 6p.m.
2. Estimated impacts for events called between 4p.m. and 7p.m.

The overall average impact on demand during both types of events is presented in Figure 21 and Table 27, below. As to be expected, and as noted in the winter impacts chapter, the demand reduction from heat pump curtailment exceeded those from water heater curtailment in all events.

The estimated impacts shown below are the average per-device impact of a successfully controlled device. A successfully controlled device in this case is defined as a device (or end-point) that the implementation contractor was able to verify actually responded to the curtailment signal. The overall percentage of successfully controlled devices (i.e., devices which realized the demand impact) is shown on the bottom row of Table 27. The majority of non-responsive end-points were non-responsive to all of the events called.

**Figure 21: Average Impact per Successfully Curtailed Device – Summer (Chart)**



Note: Impacts in this chart and the charts and tables which follow are averages across successfully controlled devices unless otherwise noted in the text.

Source: Navigant analysis

**Table 27: Average Impact per Successfully Controlled Device – Summer (Table)**

	Water Heaters	Heat Pumps
4p.m. - 7p.m. Events (kW)	0.24	0.38
3p.m. - 6p.m. Events (kW)	0.12	0.53
Average % of Devices Successfully Curtailed	57%	64%

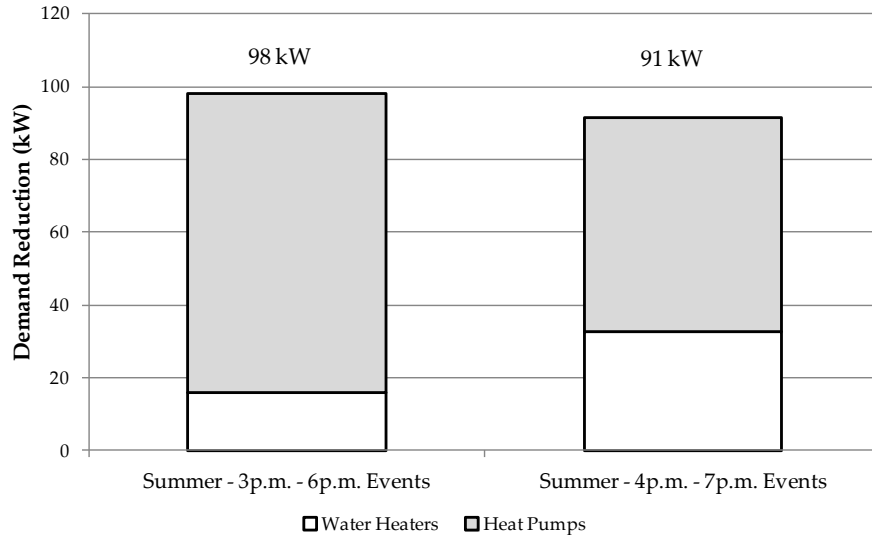
Source: Navigant analysis

When estimated impacts are shown in tabular format, in some cases cells contain “N/A” rather than a numeric estimate. In these cases, the estimated impact is not statistically significant at the 90% level. This means that it is impossible to be sure, with 90% confidence, that the estimated impact is not just the result of random variation in the data rather than the impact of the experimental treatment. In most cases the evaluation team treats these estimates by conservatively assuming that since no impact can be confirmed to be statistically significant, no impact exists. It should be noted that for the summer impacts, there exists one exception to this general guiding principal.

The average aggregate impact that the pilot had on Bainbridge Island load for summer events between 3p.m. and 6p.m. and for summer events between 4p.m. and 7p.m., split up by type device curtailed, may be observed below in Figure 22.



**Figure 22: Average Aggregate Impact - Summer**



The precise figures making up Figure 22, as well as the average percent of load switches that responded to the control signal are shown in Table 28 and Table 29, below. The principal driver of the difference in impacts observed between the two types of events is the temperature at the time of the event on the days in question. Because there were so few of the two types of summer events, the average impacts are more susceptible to being skewed by weather than for those estimated for the winter events.

**Table 28: Average Aggregate Impact – Summer 4p.m. – 7p.m. Events (Table)**

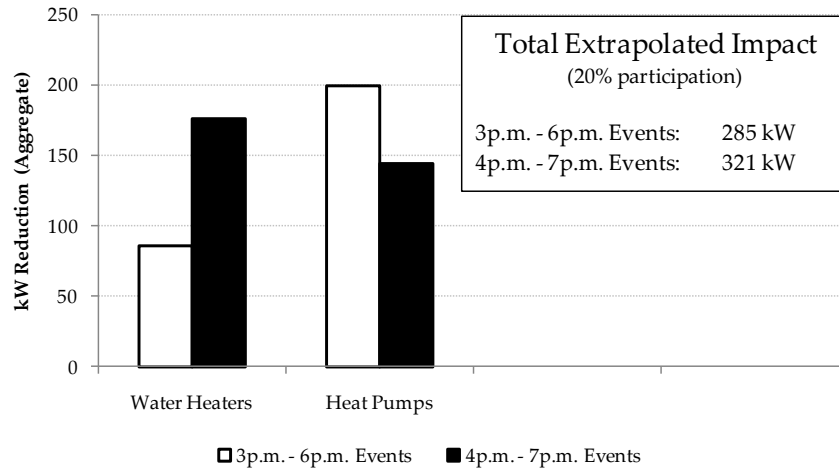
	Water Heaters	Heat Pumps	Total
Average Aggregate Impact (kW)	16	82	98
Average # of Participating Devices	486	225	
Average # of Devices Successfully Curtailed	133	155	
Average % of Devices Successfully Curtailed	27%	69%	

**Table 29: Average Aggregate Impact – Summer 3p.m. – 6p.m. Events (Table)**

	Water Heaters	Heat Pumps	Total
Average Aggregate Impact (kW)	33	59	91
Average # of Participating Devices	486	225	
Average # of Devices Successfully Curtailed	133	157	
Average % of Devices Successfully Curtailed	27%	70%	

**Potential Aggregate Impacts on Bainbridge Island.** One of the objectives of the pilot was to estimate the potential impact that would result from the wider deployment of such technologies in the PSE service area. Using Bainbridge Island as an example, the evaluation team extrapolated the aggregate demand impacts for summer events if PSE were to be successful in recruiting 20% of its approximately 6,700 Bainbridge Island customers to participate in a residential DR program. These extrapolated aggregate impacts assume that the distribution of devices would be identical to that of the pilot, that the same percentage of end-points would be successfully curtailed as in the pilot, and that the pilot participants are representative of the broader Bainbridge Island population. Under these assumptions, a summer program could be expected to provide on average, approximately 300 kW of demand reduction.

**Table 30: Extrapolated Aggregate Impact by Device Assuming 20% Participation - Summer**



Source: Navigant analysis

### 5.1 3p.m. to 6p.m. Events

In this sub-section estimated water heater impacts are discussed first, followed by estimated heat pump impacts.

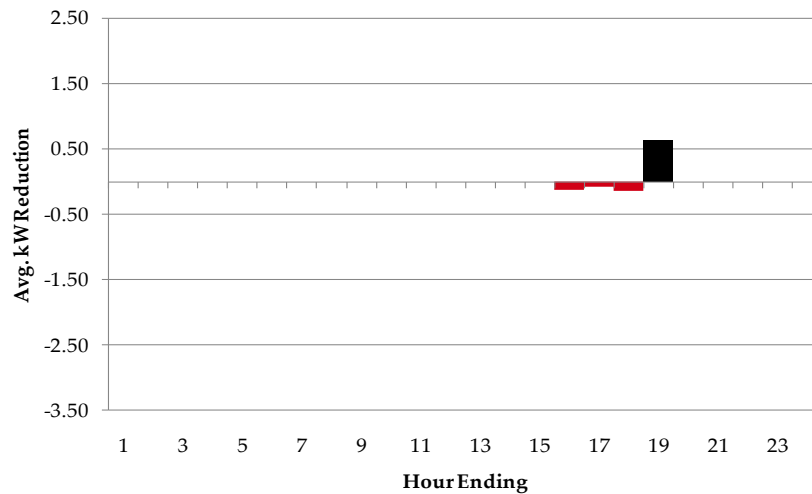
#### 5.1.1 Water Heaters

The average impact of successful water heater curtailment during the summer between 3p.m. and 6p.m. is presented in Figure 23 and Table 31 below.

As noted earlier the evaluation team typically treats non-significant estimated impacts as being functionally the same as zero. In some cases this approach needs to be tempered with a certain amount of flexibility, recognizing that a group of estimates encompassing both demand reduction and snapback impacts must be internally consistent.

In this case, demand reduction impacts are all non-significant (see Table 31, below) and yet there is a statistically significant snapback impact. In this case, therefore, there is sufficient evidence (i.e., the significant snapback) to suggest that despite the non-significant demand reduction impact estimate there must, in fact, be some demand reduction during the curtailment period. This means that despite the demand reduction impacts not being statistically significant, they are treated, in this case, as though they are.

**Figure 23: Average Impact per Successfully Curtailed Water Heater**



Source: Navigant analysis

**Table 31: Average Impact per Successfully Curtailed Water Heater**

Avg kW Impact						
3pm - 4pm	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-0.12 (N/A)	-0.09 (N/A)	-0.15 (N/A)	0.64	N/A	N/A	N/A

N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

It is important to note that unlike all of the winter impacts, which were estimated over ten different events, summer impacts for events from 3p.m. to 6p.m. were estimated over only two different events, both in the same week. The non-significant results observed are a function of both the magnitude of the impact estimated and the number of data points (observations) available to estimate it. This means that the impacts shown above may in fact be truly present, but that there is insufficient data available to the evaluation team to be 90% sure that these are not simply the result of random variation in the data<sup>10</sup>.

<sup>10</sup> As the number of observations from which information to estimate impacts diminishes, the possible range of estimated values (called the confidence interval, typically seen as a +/- figure attached to an estimated impact, e.g. 1 kW +/- 0.2 kW) increases. Once this range of possible values straddles the zero then the estimate is described as non-significant because the hypothesis that there is no impact – that the estimated impact is simply the result of chance variations in the data – cannot be reasonably rejected.

What is most interesting about the result above is how their pattern matches the winter result for water heater curtailment – that in the afternoon, the snapback impact actually exceeds the curtailment impact. The reason for the very low demand reduction impact is relatively intuitive: the event occurs during a time of day when most people are not at home and both events called for this time slot occurred on July 7<sup>th</sup> and 8<sup>th</sup> of 2010, the Wednesday and Thursday following the Independence Day holiday<sup>11</sup>. Many participants may not have been home, particularly, if they remained away on vacation that week.

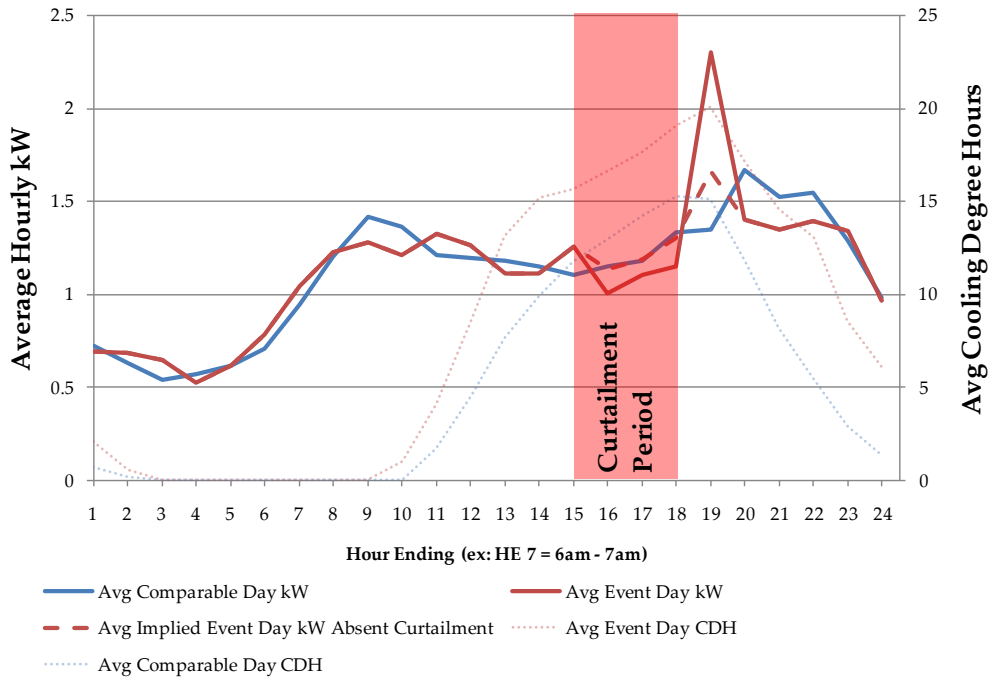
More troubling is the snapback impact which is both significant and greater in magnitude than the demand reduction impact. A likely explanation is, as noted earlier, that the magnitude of the snapback impact is due to water stored in the tanks cooling below the thermostat set points during the curtailment period. Aggregate kW demand of the water heaters likely reappeared in unison (as snapback) as reheating of the stored water began once curtailment ended.

Regardless of the reason for this anomalous result, a plot of event day consumption compared to comparable day consumption (Figure 24 below) clearly shows a snapback that is greater in magnitude than the demand reduction impact. In addition, the implied consumption absent curtailment (i.e., actual consumption less estimated impacts) is very close to the comparable day consumption.

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<sup>11</sup> July 4<sup>th</sup>, 2010 occurred on a Sunday. Monday July 5<sup>th</sup> was therefore the public holiday.

**Figure 24: Summer Water Heater Curtailment – Reasonableness Test**

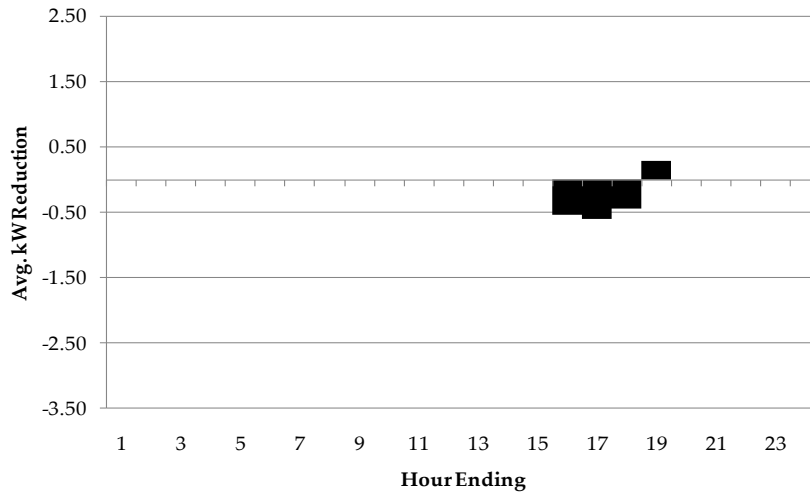


Source: Navigant analysis

### 5.1.2 Heat Pumps

The curtailment impacts observed for heat pumps (see Figure 25 and Table 32, below) are more or less in line with the expected demand reduction from heat pump curtailment on a hot summer afternoon. The snapback impact, however, appears to be very modest. The evaluation team attempted estimating a number of different model specifications to confirm the validity of this result and there was remarkable consistency in the parameter estimates obtained, leading the evaluation team to conclude that this is a relatively robust result.

**Figure 25: Average Impact per Successfully Curtailed Heat Pump (cooling)**



Source: Navigant analysis

**Table 32: Average Impact per Successfully Curtailed Heat Pump (cooling)**

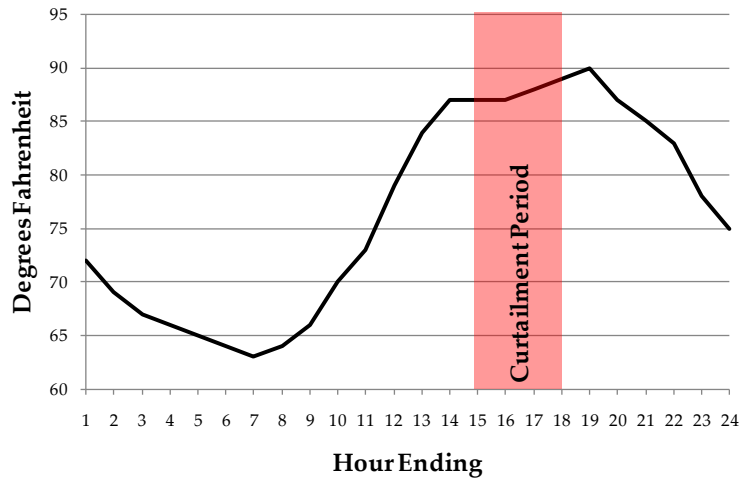
Avg kW Impact						
3pm - 4pm	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
-0.54	-0.60	-0.44	0.29	N/A	N/A	N/A

N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

A closer examination of average outdoor temperatures (see Figure 26 below) on the event days may provide further insight into why the estimated snapback impact is lower than might otherwise be expected. Recall that the estimated snapback is the estimate of the electricity consumption due to the curtailment event *incremental to what would have been required otherwise*. The outdoor temperature only peaks after the curtailment event, and when it begins to fall, it does so relatively slowly. Because the outdoor temperature was so high in the hours following the event, there would have been considerable heat pump electricity consumption following the time window of the curtailment *even had there been no event*.

**Figure 26: Hourly Temperature on July 7, 2010  
(Day of Heat Pump 3p.m. to 6p.m. Curtailment Event)**

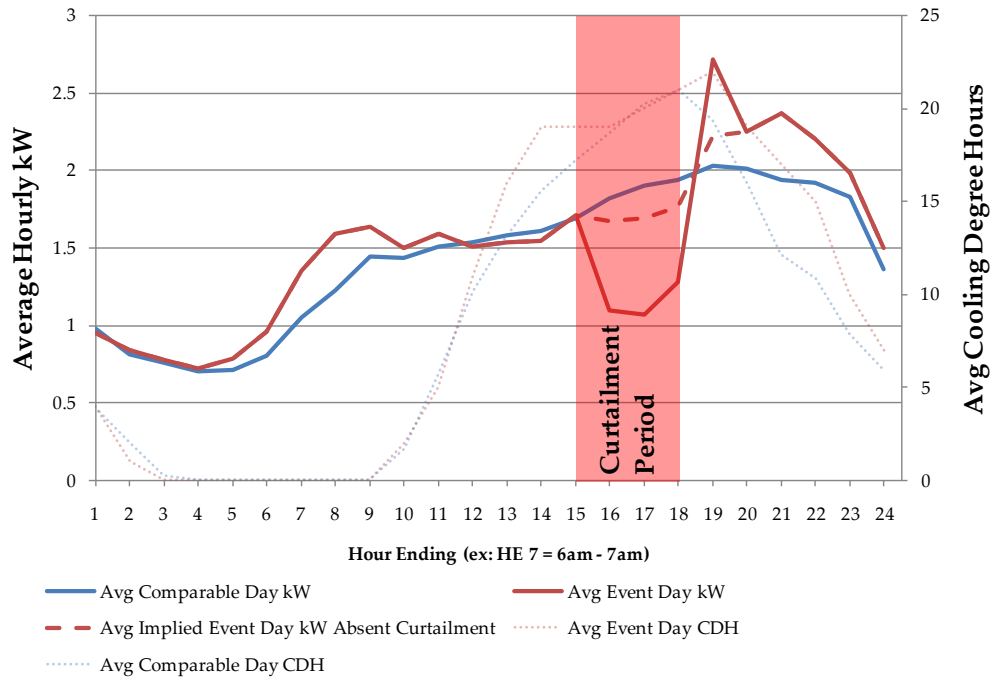


*Source: Navigant analysis, NOAA*

Thus, although there was a considerable amount of consumption following the event – certainly more than normal (see blue line in Figure 27) – most of this may be ascribed to what would have been required anyway by the abnormally warm outdoor temperatures rather than to the curtailment event itself.



**Figure 27: Summer Heat Pump Curtailment – Reasonableness Test**



Source: Navigant analysis

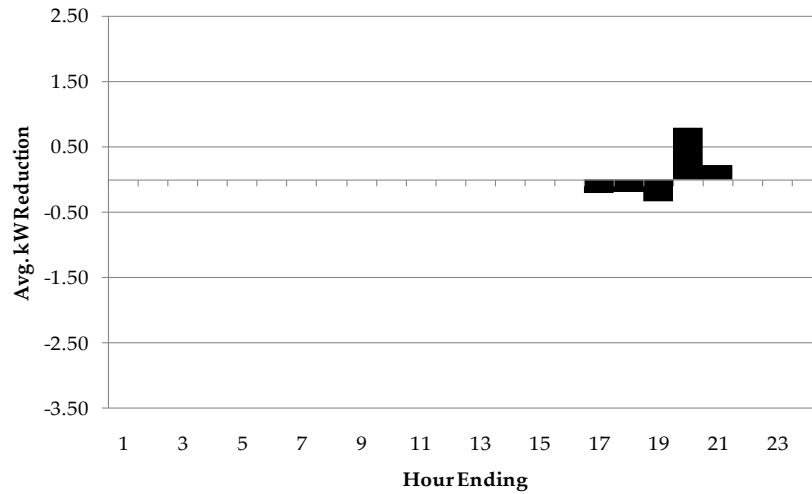
## 5.2 4p.m. to 7p.m. Events

In this sub-section, as in that above, estimated water heater impacts are discussed first, followed by estimated heat pump impacts.

### 5.2.1 Water Heaters

As expected, demand reduction impacts for water heater curtailment from 4p.m. to 7p.m. (shown in Figure 28 and in Table 33, below) are all greater in magnitude than those observed during the 3p.m. to 6p.m. curtailment events. Not only was the period of curtailment more likely to be coincident with the presence of a participant in the home (i.e., more hours of curtailment outside of normal working hours), but the three days on which events were called (July 26<sup>th</sup>, August 13<sup>th</sup> and August 16<sup>th</sup>) are not near enough to a major public holiday and perhaps less likely that participants would be away on vacation.

**Figure 28: Average Impact per Successfully Curtailed Water Heater**



Source: Navigant analysis

**Table 33: Average Impact per Successfully Curtailed Water Heater**

Avg kW Impact						
3pm - 4pm	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
N/A	-0.20	-0.19	-0.33	0.79	0.22	N/A

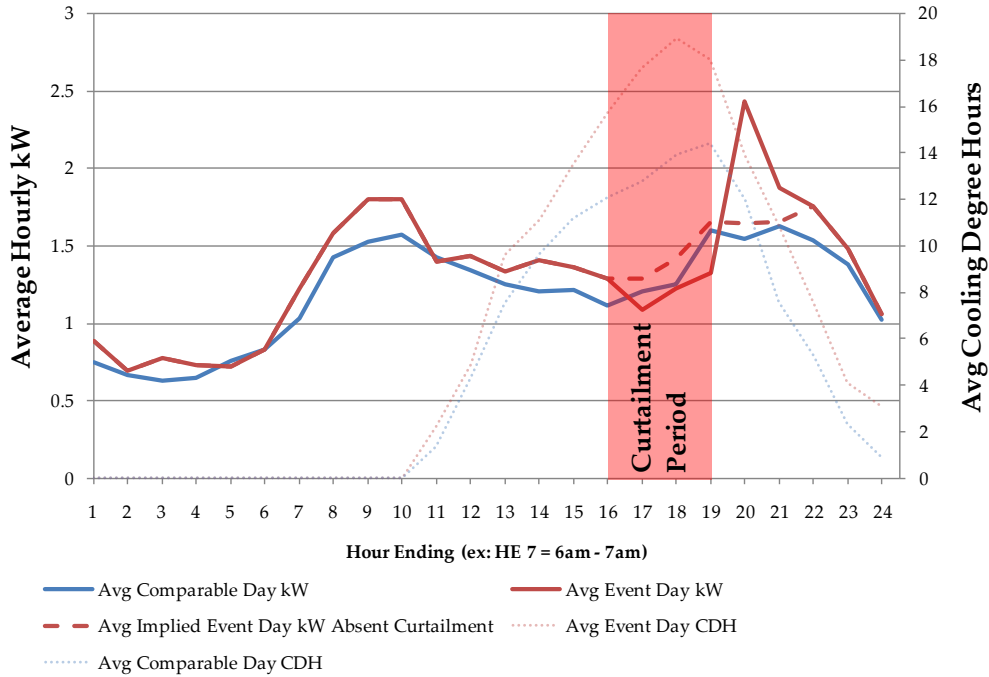
N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

Interestingly, the snapback impact is not just larger and longer lasting than for the 3p.m. to 6p.m. events (which would be expected given the more substantial demand reduction impacts) but it is still considerably greater in magnitude than the demand reductions. That is, curtailment of water heaters in this period once again led to a net increase in energy consumption. This result is common to all afternoon water heater curtailments (winter and summer) and this consistent result strongly suggests that this is the result of something systematic – perhaps the accumulation of standby consumption suggested earlier – rather than a single anomalous result due to random fluctuations in the data.

As noted earlier, the very large snapback (relative to the demand reduction) estimated is not simply an artifact of the econometric techniques used, but may clearly be observed in a plot of the data, as shown below in Figure 29.

**Figure 29: Summer Water Heater Curtailment – Reasonableness Test**

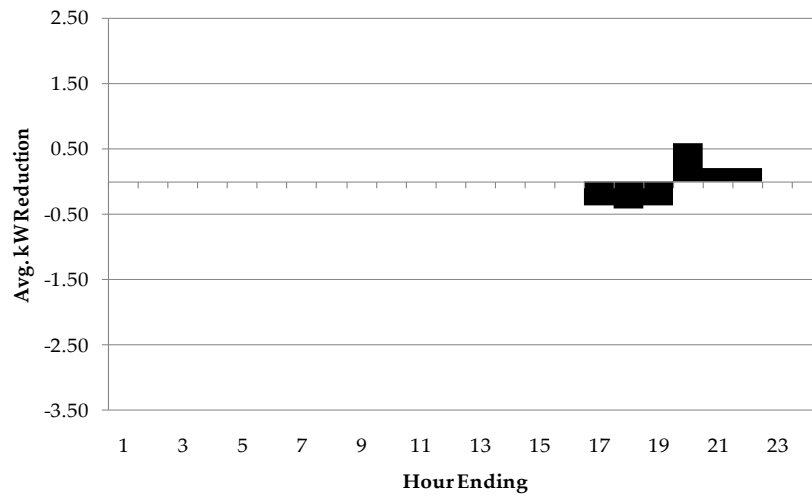


Source: Navigant analysis

### 5.2.2 Heat Pumps

The average impact of successful water heater curtailment during the summer between 4p.m. and 7p.m. is presented in Figure 30 and Table 34 below. Interestingly, the estimated demand reduction for heat pumps curtailed between 4p.m. and 7p.m. appear to be less than for those curtailed on July 8<sup>th</sup> (when the curtailment event was between 3p.m. and 6p.m.) and yet the snapback impact appears to have been greater than on July 8<sup>th</sup>. The most likely explanations for the lower than previously observed demand reduction impact and the higher than previously observed snapback are discussed below.

**Figure 30: Average Impact per Successfully Curtailed Heat Pump**



Source: Navigant analysis

**Table 34: Average Impact per Successfully Curtailed Heat Pump**

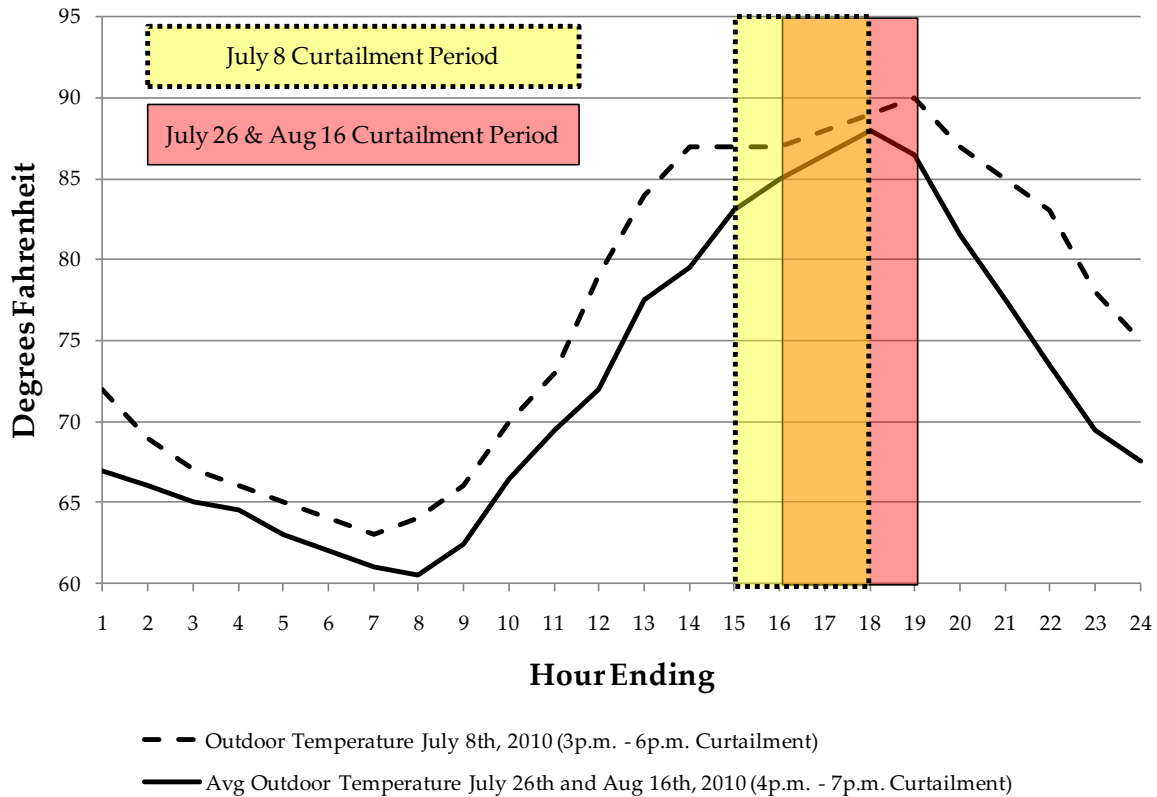
Avg kW Impact						
3pm - 4pm	4pm - 5pm	5pm - 6pm	6pm - 7pm	7pm - 8pm	8pm - 9pm	9pm - 10pm
N/A	-0.37	-0.41	-0.36	0.59	0.21	0.20

N/A = No statistically significant impact at 90% confidence level

Source: Navigant analysis

First, the lower demand reduction impacts: the reason why these are lower in absolute value than those estimated for the July 8<sup>th</sup> 3p.m. to 6p.m. event is relatively straightforward – it was warmer during the curtailment period on July 8<sup>th</sup> (3p.m. to 6p.m. event) than the during the 4p.m. to 7p.m. curtailment events on July 26<sup>th</sup> and August 16<sup>th</sup>. This may clearly be seen in Figure 31 below. Just as important as the difference in temperatures during the two curtailment events is the difference in temperature immediately preceding them. Typically, space-cooling loads lag somewhat behind outdoor temperatures. Observe in particular the gap of more than five degrees between the temperatures of the two series in the hours preceding the curtailment period. This lagged temperature effect has a considerable influence on the electricity required to cool a home, as may be observed in the magnitude of the difference between the impacts observed for the 3p.m to 6p.m. event and the 4p.m. to 7p.m. event.

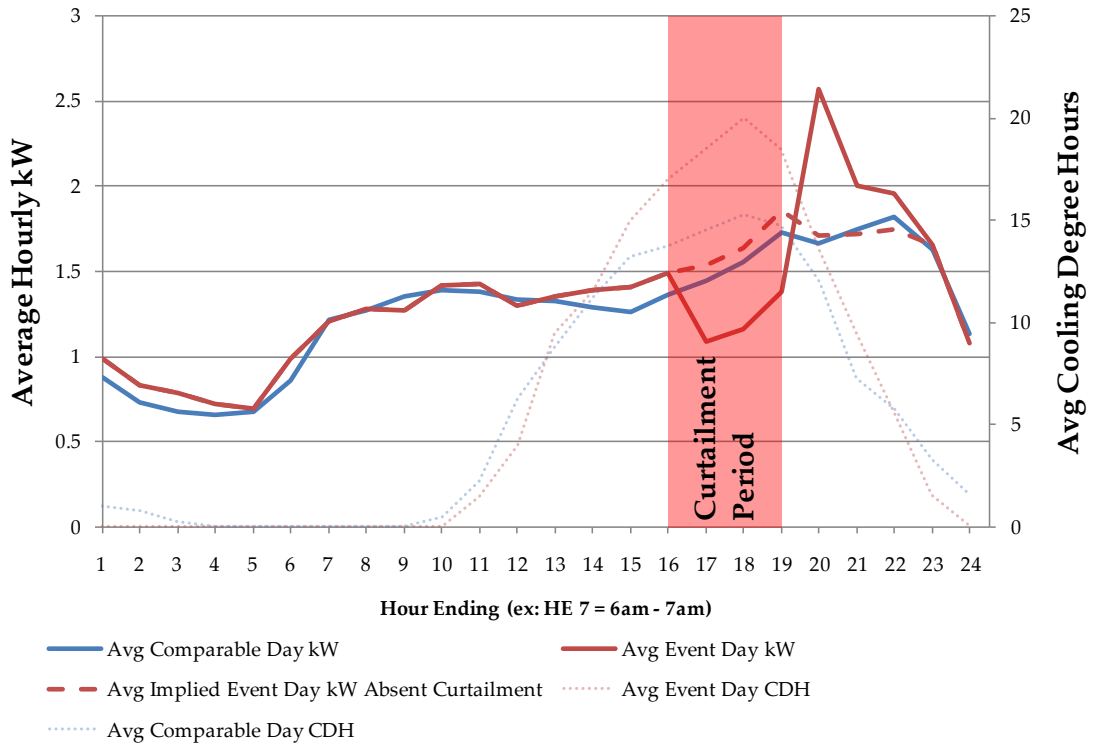
**Figure 31: Hourly Temperature July 7, 2010 compared to Average Hourly Temperature July 26<sup>th</sup> and Aug 16<sup>th</sup>.**



Source: Navigant analysis, NOAA

The larger snapback (compared with the 3p.m. to 6p.m. event) may be explained by reference to Figure 32 below and Figure 31, above. Recall that the hypothesized reason for why the snapback on July 8<sup>th</sup> (the 3p.m. to 6p.m. event) was so low was that very high temperatures following the event would have required high levels of consumption anyway, and that most of the elevated level of consumption observed following the curtailment event could be ascribed to normal behavior in the face of unusually high temperatures. Now, note that not only is the temperature immediately following the July 26<sup>th</sup> and August 16<sup>th</sup> events on average much lower than on July 8<sup>th</sup>, but it also falls at a faster rate. Put another way, absent the curtailment event the heat pump, in the hours following the time window in which the event occurred, would not have had to work as hard because of the falling temperature. That is, curtailment resulted in incremental heat pump electricity consumption following the event that would not have been required had the heat pump not been curtailed. Thus the additional consumption following the event may be attributed not to normal behavior in response to exterior temperatures, but instead to the snapback recovery effect.

**Figure 32: Summer Heat Pump Curtailment – Reasonableness Test**



Source: Navigant analysis

## Section 6. Process Evaluation Findings

The overall process findings are comprised of a synthesis of the three major components of the process evaluation. A detailed analysis of each of the three components may be found after the principal findings presented below. The three major components are:

1. In-depth Interviews (detailed analysis beginning on page 77)
2. Customer Surveys (detailed analysis beginning on page 82)
3. Focus Groups (detailed analysis beginning on page 103)

A rigorous analysis of the results of all three of these activities contributed to the principal findings outlined below. Recommendations based on these findings are presented in the final chapter - Conclusions and Recommendations, below.

Overall, the evaluation team considers the DR Pilot to be a success insofar as pilot programs are expressly employed to identify potential issues for large-scale implementation. Furthermore, overall satisfaction was generally high among participants. The principal findings derived from the analysis of the three components of the process evaluation are as follows:

***Finding #1: Overall, participants were satisfied with their experience in the Bainbridge Island Demand Response Pilot and would recommend it to others.***

. More than three-quarters of participants expressed interest in remaining in the program and would recommend it to a friend. A large majority of participants thought the annual incentive payment was sufficient compensation for participation in the program.

***Finding #2: Many customers were motivated to participate in the program by altruistic reasons; dropouts cited varied reasons for leaving.***

Overall, participants and dropouts indicated they were motivated to participate in the Pilot more by altruistic and environmental reasons than by a desire to save money or receive an incentive. To “take an active role in energy conservation” was the most frequently cited motivation for participation by participants. Dropouts cited a variety of reasons for discontinuing participation, including equipment problems, physical discomfort, and increased utility cost. However, no specific trends were identified.

Some dropouts cited increased utility costs as their reason for leaving the program.. It is important to note participants generally expected to save money through their enrollment though savings were not discussed in any of the pilot communications provided by the utility. Some participants expressed familiarity with, and openness to, adopting time-of-use rates.

***Finding #3: Most participants remained comfortable during curtailment events and maintained their normal activities.***

While overall satisfaction with curtailment events was high, it varied across technologies being controlled in their homes. Although a large majority of participants with enrolled water heaters, baseboard heaters, or forced air furnaces remained comfortable and undisturbed during curtailment events, more than half of heat-pump participants reported needing to take alternative actions to stay warm during events. Most heat pump participants recalled experiencing an event, whereas less than half of water heater participants could recall an event occurring.

***Finding #4: Participants did not exhibit a complete understanding of the program and demand response, although awareness of the program was high throughout the population.***

Program awareness was high among non-participants and participants alike, with the vast majority of them viewing the promotional letter as an effective means of communication. Newspaper articles also appeared to be a successful means of building widespread familiarity with the program. However, the majority of participants and non-participants did not demonstrate an understanding of demand response, either professing uncertainty or providing a response that did not reflect an understanding. Many participants expected to save money on their utility bills despite there being no mention of such a benefit in program materials. Lastly, some participants continued to express reservations about loss of control over heating, which might reflect lack of awareness of the option to opt out of up to 50% of events.

***Finding #5: Participants were generally dissatisfied with program technologies, particularly the Digital Gateway and programmable thermostat.***

Difficulties with program equipment appeared to be the largest factor in customer dissatisfaction with the program. Network connectivity with the demand response management software and the load switches and thermostats via the internet gateways and home routers was inconsistent for many customers. Roughly 15% of customers typically lacked connectivity at a given time. There appeared to be a number of factors involved in loss of connectivity. Technical staff of the equipment provider was unable to put forward a broadly reliable solution. Implementation staff speculated, in some cases, the internet gateway did not re-establish connectivity quickly through the home's wireless router following temporary power outages.



These electrical service outages typically occur during wind storms that impact the island in winter. A number of participants found the programmable thermostat to be difficult to operate, and lacking in desired features compared to their original thermostats. Later, they received notification of a potential safety hazard caused by a flaw in the thermostat electrical circuitry. Only half of participants were satisfied with the website. Satisfaction with was higher among those with enrolled water heaters.

For a potential future program of expanded scale, PSE would likely want to consider ways to invest in more completely pretesting and evaluating performance and reliability of hardware, communications and software of multiple suppliers as a means of providing a more seamless user experience and enhanced program performance.

***Finding #6: Contractors and participants experienced numerous challenges in installation.***

The DR equipment worked immediately (at the time of initial installation) for only about half of participants. In some cases, full installation of equipment was delayed. Some participants perceived their installations as hasty. A few perceived that the load switch was installed in a location that they determined created an appearance issue. Some customers felt there was wall damage associated with wiring penetrations associated with load switch installation. Almost one-third of participants surveyed were dissatisfied with an aspect of the thermostat installation for their heat pumps. Focus group participants cited this as a possible barrier to the program's future success. One installation technician indicated that the multiple types of equipment used in this pilot made the installation process complicated and increased the likelihood of service calls and delays. Participant satisfaction varied greatly across technologies. Although PSE provided copies of manufacturer product information to the field installation contractor to distribute to participants at the time of **installation**, a number of participants in early installations noted the technician did not provide this information during the initial installation visit. The unsightly installation of some equipment would become an even greater issue in a large-scale, permanent program. Contractor technicians may be viewed by participants as closely linked to PSE and affect perceptions of the program and reflect upon the company.

***Finding #7: Most participants were satisfied with customer service, but many customers found it difficult to contact customer support staff and resolve problems.***

The majority of participants appeared to be satisfied with their customer service experience. However, nearly one-quarter of participants who contacted a service representative were dissatisfied in some way with their experience. It appears that some participants' difficulty with customer service exacerbated frustrations with the equipment. A number of focus group participants who left the program suggested that explanations or apologies from customer support staff would have changed their decision to drop out. In surveys and focus groups,

customers widely expressed a desire for accessible, effective, and responsive customer service. Participants demonstrated confusion over whom to contact for assistance, and could benefit from a single point of contact with extended operating hours.

#### Findings from the In-Depth Interviews

In-depth interviews were conducted in May 2011 with three PSE staff (including the program pilot manager), two staff members from the external implementation team, two ESV staff, and one technician from the electrical contractor. In addition to providing details of program implementation, the interviewees were asked to comment on program successes and challenges, detailed below. The objectives of the in-depth interviews were to gain a more thorough understanding of program processes and to identify specific areas of program delivery where inefficiencies and/or areas in need of improvement may exist.

#### 6.1.1 Summary and Findings

Overall, each felt as if they learned a significant amount about the design and implementation of these types of programs. They identified a number of successes and challenges, which are described below.

#### Pilot Successes

1. **The rate of customer enrollment was higher than that of similar programs.** The program recruited approximately 530 customers out of the 6,700 targeted, meaning that almost 8% of those targeted participated in the pilot. According to one implementation staff person, the participation rate for similar programs is around 5%.
2. **Installation appointments went smoothly.** Implementation staff reported that the call center operated by the external implementation team was able to schedule appointments in a smooth and timely manner. The installation contractors were effective at securing the necessary permits for the electrical work, complying with codes, and performing the installations in a timely manner.
3. **For those customers whose communications and switching equipment have maintained internet connectivity with the load management system, the technology has performed as expected.** Although there have been challenges with the equipment, the pilot has been able to use the broadband internet connection with the home area network for two-way communication with the installed thermostats and load switches. Other technology-based DR programs have previously used paging equipment, which only sends a one-way signal and involves a monthly fee. The two-way signal used for the PSE pilot means it is possible to know whether the equipment received the signal and pinpoint problems. The communications equipment has also allowed the ESV to remotely update equipment (e.g., the thermostat firmware was updated during the course of the pilot).

4. **Not many customers have opted out of curtailment events.** Participating customers have the option of opting out of any curtailment event by either calling the external implementation team or PSE, or by accessing the website (heat pump opt out only). Customers receive the annual \$50 participation incentive as long as they participate in more than 50% of curtailment events. According to program staff, as of May 2011, there were only two events for which any customers had opted out, and across these two events, there were only two customers that opted out of each event.

### Pilot Challenges

1. **The equipment only worked right away for about half of the customers.** Some of the equipment was defective, and this was not known until the technicians were onsite at the customer's home. After this happened on several occasions, the external implementation team decided to pre-test all the equipment so that they would not have to use time in the field to determine whether equipment was faulty once at the customer's home.
2. **Heat pumps have presented a unique control challenge.** Heat pumps are controlled through the thermostat, and programming the thermostat to properly cycle off heat pumps during a curtailment event can be complex. Also, there may be a greater occurrence of "snapback" effects after a winter curtailment event involving a heat pump, and PSE staff were concerned that some customers may have experienced higher utility bills because of this. One staff person explained that under normal circumstances, with a two stage heat pump, the compressor operates above a certain ambient temperature (according to another staff person, usually 35-40° Fahrenheit for an area like Bainbridge Island), and below that temperature, added heating from electric resistance elements (heat strips) must be used to supply the heat requirement of the home not met by the compressor. This staff person conjectured that snapback could potentially be exacerbated because when the heat pump is cycled off for a curtailment event, the electric heat strips may then be more likely called into operation after the curtailment event. This is because the temperature differential (current vs. desired) is now greater than it would be had the heat pump been operating normally during the time of the curtailment event. This staff person stressed that the explanation for heat pump snapback is a theoretical conjecture at this point, as very little research currently exists regarding the effect of thermostats for demand response programs with heat pumps. However, this staff person suggested that if the program is to be continued or repeated elsewhere, PSE may want to consider using switches on the electric heat strips and no control on the compressor.

3. **The thermostats were recalled in October 2010 for safety reasons.** The US Consumer Products Safety Commission and White-Rodgers, the manufacturer of the thermostat model used for the pilot, agreed on a voluntary national product safety recall. Nationally, several thermostats had developed an overheating condition that presented risk of a fire hazard. A manufacturing defect in an electronic circuit permitted small amounts of electricity to back feed into the two AA batteries used to retain the clock setting in the thermostat during power outages. Several cases of battery overcharging and electrolyte leakage onto nearby circuitry resulted in overheating and risk of fire danger. For the recall, customers were simply asked to remove the batteries from the thermostat. Unfortunately, this means that every time there is a power flicker or outage or the power is turned off in the customer's home, the thermostat clock setting needs to be reprogrammed. Although this does not affect the ability of the thermostat to receive a signal and initiate a curtailment event, it means that customers may get frustrated with the inconvenience of having to reprogram the time setting in their thermostats. Furthermore, the time setting can cause heating/cooling to occur at unintended times, because the thermostat programming is time-dependent. More than one staff person noted that Bainbridge Island tends to experience more frequent power outages than other areas, at least partly due to fall and winter storms with high winds and the great number of large trees present on the island. Unplanned outages occurred on 11 days between October 1, 2009 and April 1, 2011 on parts of Bainbridge Island.
  
4. **Loss of internet-over-broadband connectivity between the thermostats and load switches and the head end load management software means that as many as 35% of participating customers are "disconnected" from the network at any given time.** These customers are not receiving a signal and their equipment cannot be cycled during a curtailment event. This number is particularly high compared to what the ESV staff reported with another utility DR program using similar equipment. Reported experience for another utility is that around 15% of customers are typically not connected, much lower than the 35% reported by the staff operating the program at PSE. Reasons for the higher percentage of disconnected customers are not clear, although staff speculated that it could be due to the higher number of power outages that occur on the island, and due to some unknown issue with the equipment that causes it to not immediately reconnect for some customers after a power outage. Although the equipment should automatically reconnect once power is restored, these issues have required service calls to some customers' homes to reconnect them to the network.

5. **Notifying and reconnecting disconnected customers has been challenging.** Customers are not necessarily aware if they are disconnected from the network, unless they monitor the indicator lights on the gateway, router, or load switch or check their thermostat status on the website. Thus, PSE has worked to notify disconnected customers of their status by sending letters to all disconnected customers and placing calls to customers who did not respond to the letter. However, PSE was unable to reach all customers to reconnect them. Staff noted that it is somewhat of a moving target, because the customers who are disconnected one month are not necessarily the same customers that are disconnected the following month. Some reasons that customers could become reconnected on their own are if they plug their gateway back in or switch on a power strip serving the gateway. Or the equipment could come back online if the customer resets the router. This makes it very challenging to notify and reconnect customers. It may also not be a customer's priority to make sure they are connected, and a service call to re-establish a difficult connection would require the customer to be present at home; this is typically an inconvenience to the customer and a high cost to the program.
  
6. **The pilot relies on the customer to power the digital gateway, meaning there is room for "operator error."** Customers may inadvertently unplug power strips that the communications equipment is plugged into, or if they switch Internet providers, the new provider may fail to plug the digital gateway back in. The external implementation team and the electrical contractor have worked to make sure customers are educated and realize that they should not turn off power strips or unplug the gateway, so this should not be a large contributor to disconnected equipment. However, several program staff mentioned that this is a challenge for some customers.
  
7. **Because of the large number of heat pumps enrolled in the pilot, some staff persons felt that the installation contractors should have more HVAC knowledge.** There was disagreement on the extent to which the electric technicians had HVAC training. There were some instances in which the thermostats were set for the incorrect type of equipment, and some staff felt that this could be avoided by using HVAC technicians in addition to electric technicians. However, one staff person reported that electricians in Washington State are required to receive HVAC training for licensing purposes.

8. **Motivating customers to participate in the program can be somewhat challenging.** Staff involved with installations reported on customer hesitations in participating in the program. When technicians go out to the customer's home to install the equipment, they first ask the customer if they have any questions to make sure that they understand the program. The first question asked by many customers is how the program is going to benefit them. In particular, they want to know how much money they will save on their utility bill by participating. At this point, the customer wants more information to decide if it is worth it for them to go through with the installation and participate in the program. However, the technician cannot tell the customer that they will save a certain amount of money on their bill, as savings are very small, at best, and variable from home to home, depending on the customer's equipment, schedule, and usage patterns. Some customers may save some energy, however, some energy is likely shifted to later hours, and some customers have such a low baseline that it is difficult to realize any energy savings. The only certain financial incentive is the annual \$50 check. The technicians also explain that the program is good for the community. Customers may then want to know if the rest of their neighbors are participating; these customers do not want to be the only ones participating in the program if the primary benefit is to the community at large. In addition, some customers are motivated to participate because they want to be able to program their thermostat online, while other customers report finding this aspect confusing or may simply not be interested in this feature.
  
9. **Reasons for customer dropout are varied.** As of May 2011, somewhere between 30 and 40 customers had dropped out of the program, according to program staff. While some of these participants dropped out simply because they moved away, others dropped out because their experience in the program was less than satisfactory. Some customers have been frustrated by the thermostat recall and having to reprogram the time setting when they lose power. Others have dropped out due to comfort reasons (i.e., they got too cold when the heating equipment was cycled off or they did not have enough hot water during curtailment events). Others have dropped out because they perceived an increase in their utility bill, possibly due to the "snapback" issues with heat pumps discussed earlier. Some participants may have elected to drop out of the program because they did not observe bill savings, although the program does not specifically advertise energy savings as a benefit.

10. **No data were collected during the 2009 – 2010 winter season.** Because of this, the pilot will only have data for one winter season (rather than two) and two summer seasons. Data were inadvertently not collected due to a miscommunication issue with the implementation contractors. Because PSE did not have a way to track which customers participated fully the first year, and which equipment was receiving a signal, all customers received the \$50 incentive.
11. **PSE may want to focus on just one type of equipment if the program is expanded.** One implementation staff person suggested that the pilot program could be more successful by focusing on just one type of equipment initially. With many different types of equipment (e.g., heat pumps, water heaters, etc.), installation of the switching and communications equipment can be very complex because there are many factors the technician must consider for each installation. For example, the load switch used for the pilot is fairly complex, because it needs to be capable of being used with multiple types of heating equipment. The more complex the installation process is, the more room there is for error, and the more likely it is that the technician will have to make a service call to correct something. The more service calls, the more negative the customer experience.

### 6.1.2 Summary & Recommendations

While the pilot program has experienced many challenges, the experience of the pilot can also be considered a success because PSE has accomplished the goal of learning what the challenges are in operating a technology-based demand response program. Most of the challenges encountered throughout the pilot have had to do with the type of communications and switching equipment used in the customer's home. Before considering continuation of the existing pilot or expansion to additional portions of the PSE service territory, PSE may wish to consider ways to troubleshoot the type of communications equipment selected, or perhaps limiting the types of heating equipment that can be controlled by the program. At a minimum, PSE may want to consider how heat pumps are controlled through this type of program before continuing or expanding the pilot. Attention should also be paid to the methods used to motivate customers to participate in the program, as the motivating factors for customers living on Bainbridge Island may be quite unique (i.e., avoiding the building of additional substations) compared to different portions of the PSE service territory.

### 6.2 Customer Survey Results

The customer survey was conducted via telephone with samples of participants, dropouts, and non-participants. The telephone surveys collected data from 143 customers on customer demographics, awareness and knowledge of the program, satisfaction with installation and

customer service, motivations to participate, experience with curtailment events, and interaction with technologies.

### 6.2.1 Characterization of Survey Respondents

Table 35 presents the mean household size and respondent age by group. No statistically significant differences were detected between groups for either of these characteristics. Also, the mean household size is not statistically significantly different from the value of 2.46 presented in the U.S. Census Bureau, 2005-2009 American Community Survey. Thus, all three samples are generally representative of household sizes in the general population on Bainbridge Island.<sup>12</sup>

**Table 35: Comparing Key Characteristic of Survey Respondents**

	Participants	Dropouts	Non-Participants
Mean Household Size	2.72	2.14	2.79
Mean Respondent Age	60.9	62.4	57.8

*Source: EMI Analysis*

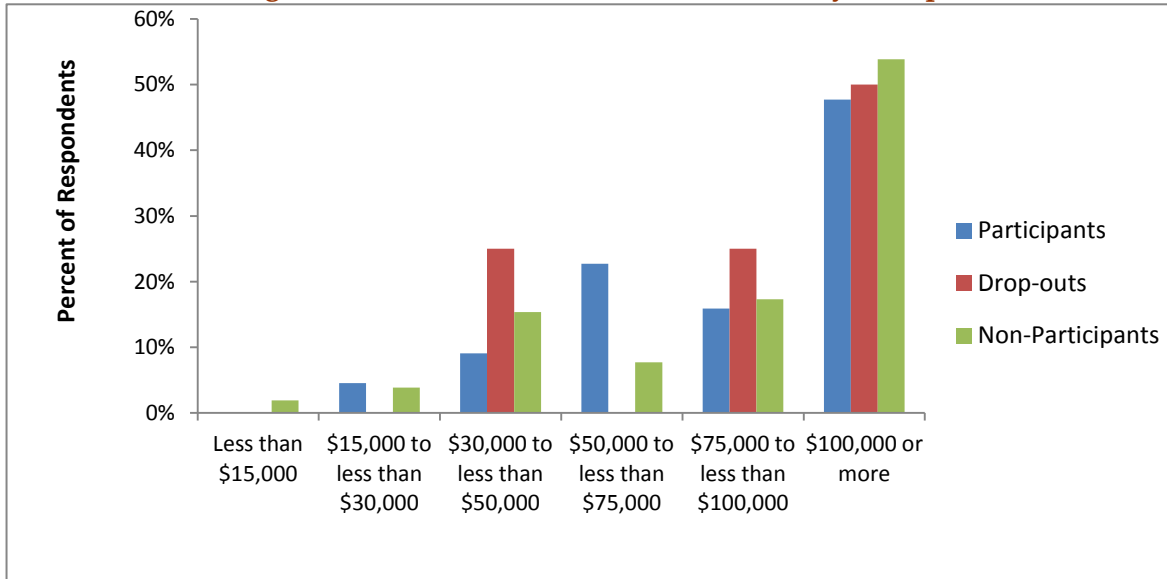
Figure 33 presents the annual household income distribution of respondents by survey type. Roughly one-half of respondents, regardless of survey type, reported annual incomes in excess of \$100,000. Though an accurate mean cannot be calculated from the surveys because the questions were presented with categorical response options and the largest category was not bounded, this data does not suggest the income levels would be any different from the mean annual household income of \$130,028 reported in the U.S. Census Bureau, 2005-2009 American Community Survey.

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<sup>12</sup> Note that the average respondent age was not comparable to census data



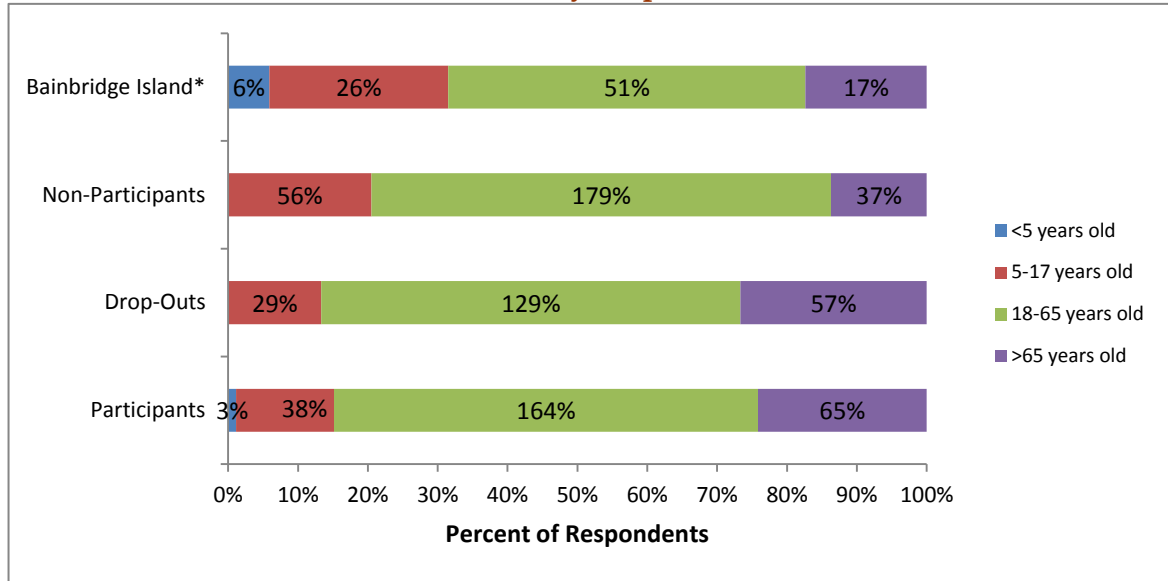
**Figure 33: Household Income Distribution by Group**



Source: EMI Analysis

Figure 34 shows that slight differences existed in the age distributions of household occupants among survey respondents as compared to the population of Bainbridge Island. In general, the samples slightly under-represent younger residents and slightly overstate older residents. However, it is important to note that according to the U.S. Census Bureau, 84% of occupied housing units on Bainbridge Island from 2005-2009 were single-family homes. Due to the nature of this pilot program, only single-family residences were eligible for participation, and as such, only single-family residences were sampled, which would lead to the results shown.

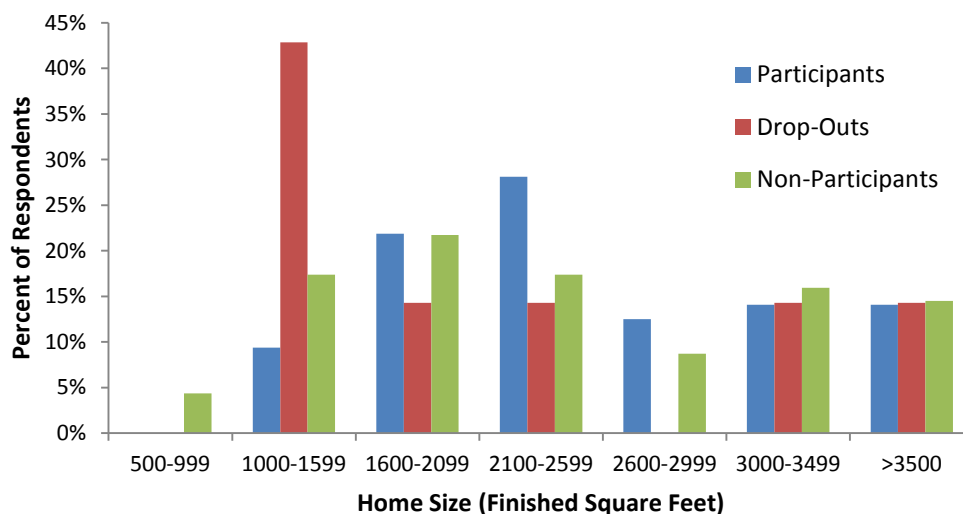
**Figure 34: Comparing Household Age Distributions: Bainbridge Island Census Data to Survey Respondents**



Source of Bainbridge Island population data: U.S. Census Bureau, 2005-2009 American Community Survey

Based on 5-year sales data from Zillow.com, the evaluation team estimates the average-single family home size on Bainbridge Island is approximately 2,234 square feet; for surveyed participants this was 2,486 square feet; dropouts 2,121 square feet; non-participants 2,338 square feet. A statistical comparison of these groups against the Zillow data was not possible due to the structure of the data available from Zillow. Nevertheless, no significant difference from the general population seems evident. Figure 35 presents the distribution of home sizes among respondents.

**Figure 35: Distribution of Home Size (in Finished Square Feet)**



Source: EMI Analysis

While the most striking result from Figure 35 might appear to be that the majority of dropouts were associated with relatively smaller homes, it is important to keep in mind that the sample size for this group was quite small ( $n = 7$ ). In all, only three actual dropouts account for this rather large spike, and each of the other categories containing dropout data only account for one dropout each. Thus, drawing any useful conclusions about the dropouts relative to home size is inappropriate.

In summary, the sampling plan allowed the evaluation team to collect data on a relatively representative sample of households on Bainbridge Island. The only notable difference detected was with the age distributions, but this could be expected given only single-family homes were included in this study.

Table 36 shows the final distribution of participants and dropouts by equipment type reported to have been enrolled in the program.<sup>13</sup> The majority of both groups participated in the program with water heaters (67% participants; 86% dropouts). For participants, heat pumps tied to a heating system accounted for about one-third of respondents (38%); heat pumps tied to an AC system accounted for about 15% of respondents. For the dropouts, equal numbers of customers were associated with electric heat, gas heat, and heat pumps tied to a heating system.

<sup>13</sup> Note that the sampling plan was not stratified by equipment type.

**Table 36: Participant and Dropout Respondents by Equipment Type**

Equipment Type	Participants		Dropouts	
	Count	% of Total Participant Respondents (n=66) <sup>1</sup>	Count	% of Total Dropout Respondents (n=7)
Water Heater	44	67%	6	86%
Baseboard Heater	3	5%	1	14%
Forced Air Furnace	4	6%	1	14%
Heat Pump (Heat)	25	38%	1	14%
Heat Pump (AC)	<u>10</u>	<u>15%</u>	<u>0</u>	<u>0%</u>
<b>EQUIPMENT TOTAL</b>	<b>86</b>		<b>9</b>	
<b>TOTAL SURVEY RESPONDENTS</b>	<b>66</b>		<b>7</b>	

<sup>1</sup> Note that the % of Total column does not sum to 100%. Customers could participate with more than one type of equipment.

Source: EMI Analysis

Among non-participants, most reported having electric water heaters (81%) and heating (71%) that would have been eligible for the program. Of those that reported heating, about 33% indicated heat pumps; 39%, reported electric heat.

### 6.2.2 Marketing, Enrollment, and Consumer Knowledge

#### Program Awareness and Marketing Efficacy

Program awareness was generally high among non-participants – more than two-thirds (67%) of the non-participants were aware of the demand response pilot program. Of additional interest was how these and other customers were first made aware of the program, and more specifically, how effective was PSE’s promotional letter introducing the program.

All respondents were asked if they recalled receiving the letter from PSE informing them of the Bainbridge Island Demand Response Pilot Program. No significant difference was detected between the three groups: 83% of the non-participants recalled this letter compared to 86% of participants and 71% of dropouts.

Of the non-participants that recalled the letter and read it, the vast majority (92%) thought the letter was an effective way of communicating with customers about the program. However, when probed further, about two-thirds these of non-participants (66%) indicated the best way to tell them about energy saving programs would be through a utility meeting; just under one-quarter (23%) preferred an email.

For participants and dropouts, instead of inquiring about the letter's general helpfulness, they were asked to rate the helpfulness of the letter on 5-point scale ranging from "not helpful at all" to "very helpful". Overall, about 84% of the participants found the letter somewhat or very helpful compared to 100% of the dropouts.

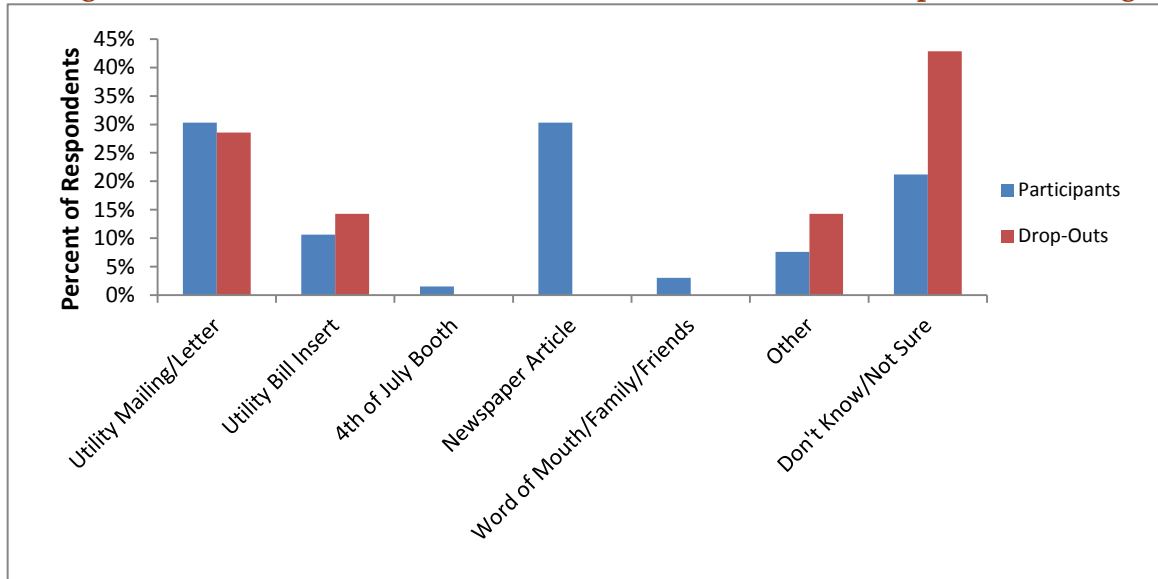
The 47 non-participants that heard of the program were also asked what other ways they might have become aware of the program (in addition to the PSE promotional letter).<sup>14</sup> More than one-quarter (28%) indicated they heard about it through a newspaper article; about 15% could not recall where they heard about the program, even though they were familiar with it.

Participants and dropouts were also asked how they first became aware of the Demand Response Pilot Program. Figure 36 shows that the most commonly mentioned avenues of awareness for the participants were a newspaper article (30%) and a utility mailing/letter (30%); about 21% of the participants could not recall where they heard about the program. In contrast, for the dropouts, while a similar proportion recalled first becoming aware of the program through a utility mailing/letter (29%), almost half (43%) could not recall where they first heard of the program.

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<sup>14</sup> Note that the way in which the non-participants were asked about how they became aware of the program was slightly different than the way the participants and dropouts were asked. For the non-participants, because we were more interested in the efficacy of the PSE promotional letter and the survey was kept relatively brief, respondents were first asked if they were aware of the program, then, whether they recalled receiving a letter promoting the program, and finally, what other factors *in addition to the letter* might have made them aware. Participants and dropouts were asked more directly how they became aware of the program – it was not a follow-up to the question about the letter, which was asked in a different section of the survey. As a result, a direct comparison cannot be made across all three groups.

**Figure 36: How Did You First Become Aware of the Demand Response Pilot Program?**



Source:

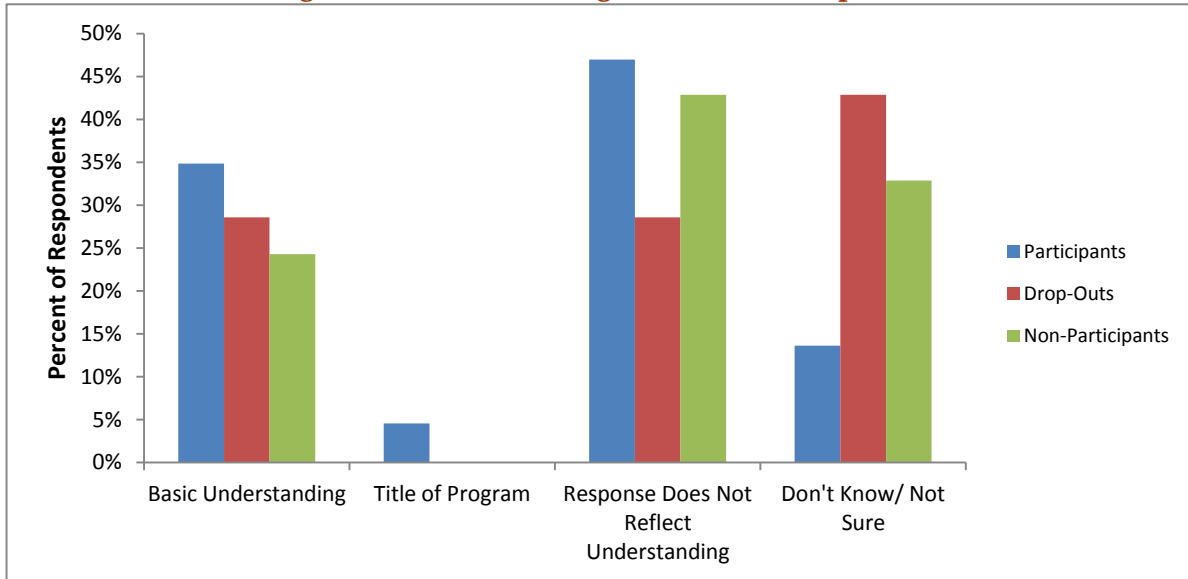
Source: EMI Analysis

In summary, while most respondents indicated they recalled the letter and that it was helpful, many people also indicated they were initially made aware of the program from other sources.

### Understanding of “Demand Response” and Program Motivations

Despite relatively high program awareness, understanding of the term “demand response” among all respondents was relatively low. Figure 37 shows that a majority of all groups either stated that they did not know what the term “demand response” meant, or responded in a way that did not reflect a basic understanding of the concept. No more than one-third of any group provided a response reflecting a basic understanding of the concept. About 5% of participants were familiar with the name of the program and its relationship to demand response, but otherwise, did not offer a clear understanding of what demand response involves.

**Figure 37: Understanding of "Demand Response"**



Source: EMI Analysis

While several respondents indicated they had a general understanding of demand and supply of energy, their responses did not quite capture the true essence of the concept. For example:

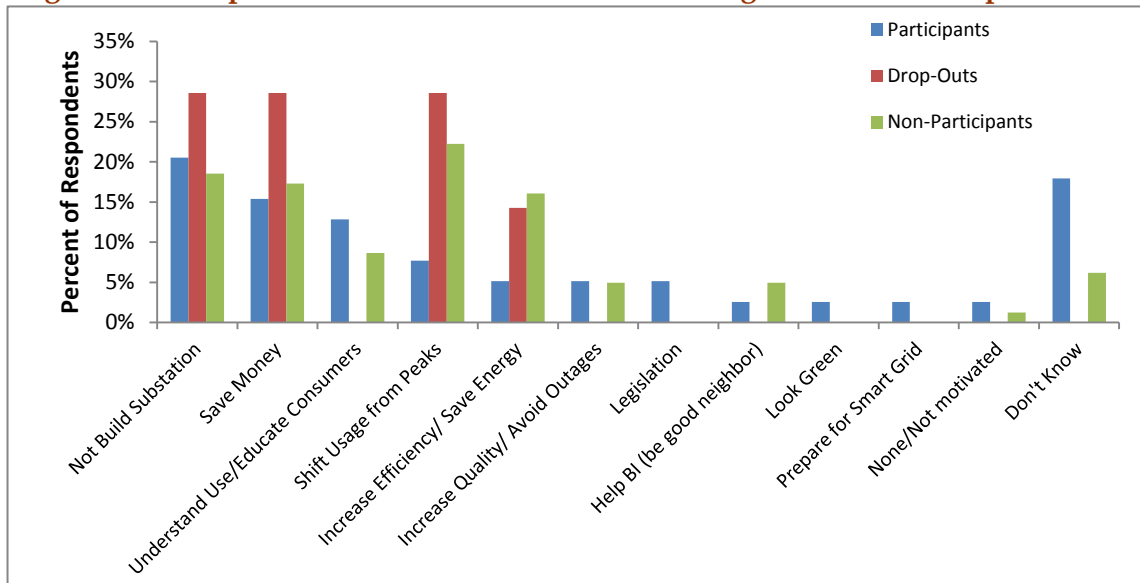
- *“Demand response would be on demand, whenever you need it.”*
- *“If I was being interrogated by a policemen, I’d say he’d demand a response. If applied to the amount of power I am using, it means I would be able to respond to my personal demand for power.”*
- *“...Just if a lot of people are pulling and using electricity, that’s the demand, and the response is getting them that electricity without fault.”*
- *“When I need it, it’s there.”*
- *“It means that you are going to be able to have power come as you need it. It would feed you power as you need it...”*
- *“I guess it means power always available whenever the demand is there.”*

Some other respondents thought demand response meant ensuring that people with a high demand for power get it at the expense of those with a low demand – reflecting a clear misunderstanding of how electricity is allocated.

Interestingly, despite not having a clear understanding of what the term “demand response” meant, Figure 38 shows that customers did generally understand Puget Sound Energy’s motivations for offering the program. Most respondents felt that the main motivations were to not build a substation on the island, save money, and to shift usage from peak periods. That

said, almost one-in-five (18%) of participants and 6% of dropouts indicated they did not know why Puget Sound Energy offered the program.

**Figure 38: Perceptions of PSE's Motivation for Offering the Demand Response Pilot**



Source: EMI Analysis

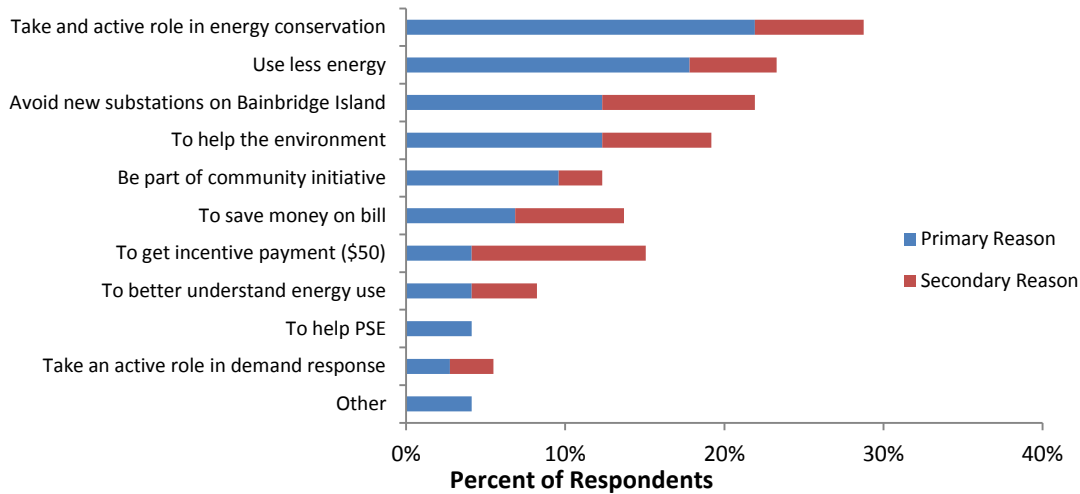
### Program Participation and Enrollment

Overall, participants and dropouts indicated they were motivated to participate in the Bainbridge Island Demand Response Pilot Program more by altruistic and environmental reasons than saving money or earning an incentive.<sup>15</sup> As shown in Figure 39, these respondents wanted to take an active role in energy conservation, use less energy, and avoid building additional infrastructure (wires and substations) on Bainbridge Island.

<sup>15</sup> Though not shown in the chart, no notable differences were found between participants and dropouts with regards to their reasons for participating in the program. The results are shown in the figure in aggregate for simplification of presentation.



**Figure 39: Reasons for Participating in Demand Response Pilot\***



\* Note that the data presented in this figure was presented as two questions: 1) What was the main reason you decided to enroll in Puget Sound Energy’s Demand Response Pilot Program? (denoted as Primary), and 2) What were the other reasons for your decision to enroll in Puget Sound Energy’s Demand Response Pilot Program? (denoted as Secondary). Respondents could provide more than one answer for the second question.

Source: EMI Analysis

Only three participants (5% of those who responded to this question) and one dropout (14%) reported being dissatisfied with the enrollment process. However, their reasons tend to reflect dissatisfaction with *the installation process and/or the program impacts* rather than the enrollment.

- *“Whatever time they told me the installation process would take, it took triple that time, and I stayed home and missed a lot of work.”*
- *“The process was fine; the results were not.”*
- *“The thermostat that was installed first was not working. The second one had directions for a different model. I can’t tell if my filter needs cleaning; I can’t reset it when it’s off, and I can’t reprogram it because it’s complicated...”*

### 6.2.3 Heat Pump - Heating and Cooling

#### Installation

About two-thirds (65%) of participants who recalled installation of the device and programmable thermostat to control their heat pump were either somewhat or very satisfied. Conversely, however, about one-third (30%) of these participants were somewhat or very dissatisfied with the installation process. One participant and the one dropout who recalled installation were neither satisfied nor dissatisfied.

Dissatisfaction with the installation process reported here was not attributable to one issue. Rather, dissatisfaction was reportedly due to the appearance of their home space where the device was installed (2), the quality of the device (2), the device leading to higher electricity use (2), or technical difficulties (2). Representative comments include:

- *“The new thermostat did not match up with the size of the old one... We have visible holes in our wall...”*
- *“The unit sticks out into the hallway and it took them more than one attempt to install it in my house.”*
- *“I could find no way to set a clock... there is no on/off button. No real way to turn it off...”*
- *“The one I had already installed was a higher quality...”*
- *“When they came to install, they made a mistake and accidentally screwed it up and my bill surged.”*
- *“Our usage has gone up and I don’t understand that because we were told that we would have lower bills if we [participated], but we do not.”*

Participants had mixed opinions of the programmable thermostats, leaning towards dissatisfaction. Ten out of 25 participants (40%) reported being either somewhat or very dissatisfied with the programmable thermostat; eight out of 25 (32%) were either somewhat or very satisfied. Three participants (12%) were dissatisfied because of the recall due to the battery leakage; six participants (24%) were dissatisfied because the programmable thermostat did not have the features that they expected or they were not able to figure out how to use it. The one dropout who recalled the programmable thermostat was very dissatisfied with it because “it caused my electricity usage to skyrocket.”

## Events

Twenty heat pump participants recalled being home when the heat pump was cycled during cold weather. One-half of these participants (50%) were somewhat or very comfortable during the event while one-fifth (20%) were somewhat or very uncomfortable during the event.<sup>16</sup> While 40% of heat pump participants continued normal activities and took no actions to keep warm during the event, more than half (55%) did take alternate actions. Of these participants who took alternate actions to keep warm, 64% started a fire and 36% wore more clothing or covered themselves with blankets to keep warm.

Of the ten heat pump participants who recall being part of the summer air conditioning program, only two (20%) recalled being home when the heat pump was cycled. Both of these participants reported being somewhat or very comfortable during the cycling event and took no actions to keep cool during the event.

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<sup>16</sup> The one dropout who recalled having a heat pump enrolled in the program was not sure if it had been cycled while they were participating.

## 6.2.4 Other Electric Heating

### Installation

The six participants who recalled the installation of the device to control heating on their baseboard heater or forced air furnace were either somewhat or very satisfied with the installation process. The one dropout who recalled the installation of the device to control heating was somewhat dissatisfied. However, based on the response given, this dropout seemed dissatisfied with the program and not the installation process: “We understood that this would be painless and that we wouldn’t have to do anything and it ended up costing us a lot of money.”

### Events

Three electric heating participants recalled being home when the heater was cycled, and they all were somewhat or very comfortable during the event and took no alternate action to keep warm. One electric heating dropout recalled being at home during a heater cycling event. This dropout reported being somewhat comfortable during the event, though they did indicate they started a fire or turned on the fireplace to keep warm.

One electric heating participant recalled opting out of a heater cycling event because “it was cold.” No heat pump participants or dropouts recalled opting out of events.

## 6.2.5 Water Heating

### Installation

Of the 38 participants and four dropouts who recalled the water heating control installation process, satisfaction was generally high. Most participants (89%) who recalled the installation process were either somewhat or very satisfied with the process; only 8% were either somewhat or very dissatisfied. Two out of four dropouts (50%) who recalled the installation were either somewhat or very satisfied; only one (25%) was very dissatisfied.

Similar to the heat pumps, respondents that reported dissatisfaction seemed particularly troubled with the appearance of the area where the control device was attached in their homes. In addition, one participant noted that a mistake in the installation led to a bill surge that has yet to be resolved. Another participant noted that the installation process took too long.

Also, based on follow-up responses, it seems the contractors performing the installation did not meet the customers' standards:

- *“Because I don’t think they spent enough time checking where the electrical sources were and how you tie into this thing. They could have checked more where it connects to the hot water heater; they made an ugly hole in the wall.”*
- *“It’s unsightly, and I don’t think they have any intention of replacing it, and in the long run, they intend to leave it there forever, unless they take it out which I think they should do. They should drywall, and spackle, and paint it to make it look normal.”*
- *“When they came to install, they made a mistake and accidentally screwed it up and my bill surged. They came out and admitted they screwed up and didn’t do anything about it. No one has ever come back and fixed it or given me my refund.”*

## Events

Seventeen participants and one dropout believed that Puget Sound Energy had cycled their water heater since they joined the program. Of the participants that did recall a water heater cycling event, more than one-half (59%) indicated they were home during the event. The one dropout did not recall if anyone in his household was home during the event. Of the participants that were home during the event, two noticed reduced availability of hot water. However, they continued normal activity during the event and did not take any alternative actions to acquire hot water.

No participants and one dropout recalled dropping out of a water heater cycling event. The one dropout opted out because of a conflict with their wireless connection to their Internet service.

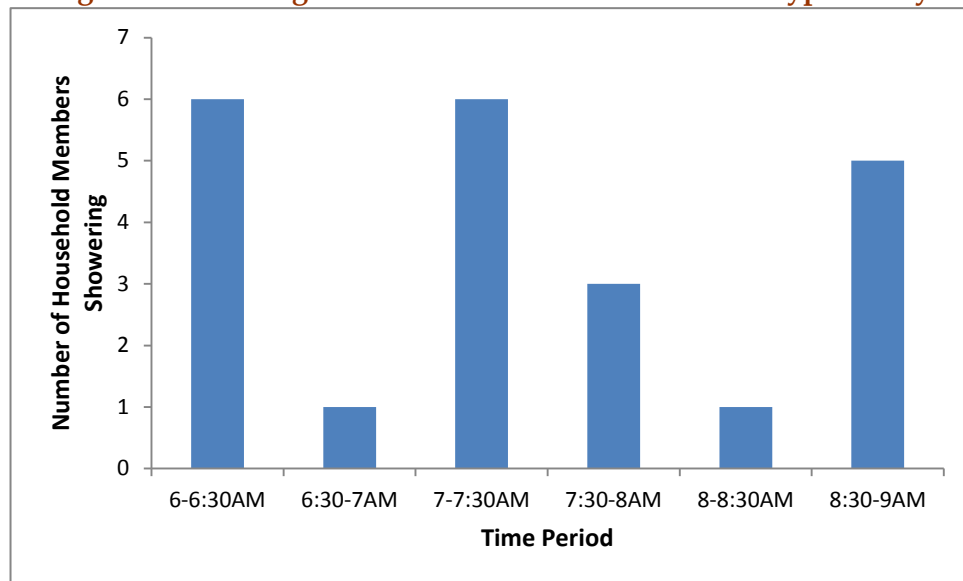
Based on these responses, it appears that the hot water cycling events do not cause significant disruption to regular activities. People who noticed that the event was occurring did not take alternative actions, and the only opt-out was due to a technical issue rather than not wanting to lose hot water services.

## Morning Water Usage

To better understand water-heating demand as it relates to the 6:00 AM to 9:00 AM curtailment period, participants who elected to have their water heater cycled as part of the program were asked to provide information about morning showering patterns in their household. In all, 68% of participant respondents provided this information. Also, because of the unique commuting circumstances existing for residents of Bainbridge Island, questions related to employment location and time spent daily on the Island were also included in the participant survey to inform subsequent analyses with this data.

In the survey, participants were asked how many people in their household shower in half-hour increments between the hours of 6:00 AM and 9:00 AM. Figure 40 shows the number of total household residents that shower in each half-hour block. Over half (59%) of the household members for which we have data indicated shower times between 6:00 AM and 7:30 AM; the remaining people take showers between 7:30 AM and 9:00 AM.

**Figure 40: Morning Household Shower Demand on a Typical Day**



Source: EMI Analysis

Typical shower times may be concentrated in the first half-hour between 6:00 AM and 7:00 AM and between 7:00 AM to 8:00 AM due to ferry departures at 7:05 AM and 8:00 AM for those working off the island. Almost one-half of the responding participants indicated they were employed full- or part-time. Of those employed, over one-half (53%) indicated that they were employed off Island. Notably, 45% of participating customers indicated they were retired, likely contributing to the relatively large number of people reporting showering later in the day outside of the 6:00 AM to 9:00 AM curtailment period.

When interpreting this data, it is important to note that only about 30% of the household members were reported to shower during the curtailment period. Though not provided as a specific follow-up, many respondents provided additional information allowing the evaluators to determine that about 21% of the household residents shower later in the day; 3% earlier. About 7% stated that household shower use varies too much to say. In all, showering times were indeterminable for about 40% of the reported household members.

## 6.2.6 Website

Over one-half of both participants (58%) and dropouts (57%) were aware of the website. About two-thirds of those aware of the website (33% of participants; 43% of dropouts) indicated that they had used the website while participating. There was general dissatisfaction with the website as a tool; none of the dropouts and only half of the participants who used the site were somewhat satisfied or very satisfied with it.

Dissatisfied respondents found the website to be difficult to use. In general, they reported having difficulties logging in and figuring out how to interact with the website.<sup>17</sup>

- *“I didn’t think it was well designed or easy to use. It wasn’t clearly labeled in layman’s terms”*
- *“The website didn’t work...when we try to set the heating program, we couldn’t be sure that’s the program being used. We are unable to modify the settings.”*
- *“When I was disconnected... I was not able to reprogram it because it did not acknowledge my password.”*
- *“It didn’t work. We could get on the website, but, a lot of the time, we couldn’t log in.”*
- *“I could not log in and get what I needed.”*

## 6.2.7 Overall Program Satisfaction

### Responsiveness to Program Questions

As shown in Table 37, just over one-third of participants (38%) and just over one-half of dropouts (57%) recalled contacting someone associated with the program during their participation for additional information or assistance. Notable is that while about one-half of participants who contacted someone for assistance had reported having a heater enrolled in the program; *water* heaters dominated the program (see Table 36). This seems to indicate a relatively greater need for assistance among heater enrollees in contrast to water heater enrollees. While it cannot be definitively determined from the responses to this survey, this may be due to the additional technology used for heater enrollees compared to water heater enrollees.

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<sup>17</sup> Note that all of the dissatisfied respondents had a heating system enrolled in the pilot.

**Table 37: Did You Ever Contact Anyone for More Information or Assistance?**

	Participants		Dropouts		Total	
	Count	% of Total	Count	% of Total	Count	% of Total
Yes	25	38%	4	57%	29	40%
No	39	59%	3	43%	42	58%
No Answer	2	3%	0	0%	2	3%
<b>Total</b>	<b>66</b>	<b>100%</b>	<b>7</b>	<b>100%</b>	<b>73</b>	<b>101%*</b>

\* Note that total exceeds 100% due to rounding.

Source: EMI Analysis

There was some confusion among the respondents who did contact someone regarding who they contacted. While overall, just over one-half of all respondents (52%) said they contacted Puget Sound Energy, and 7% indicated they contacted the ESV, 41% of the respondents were not sure who it was they contacted.

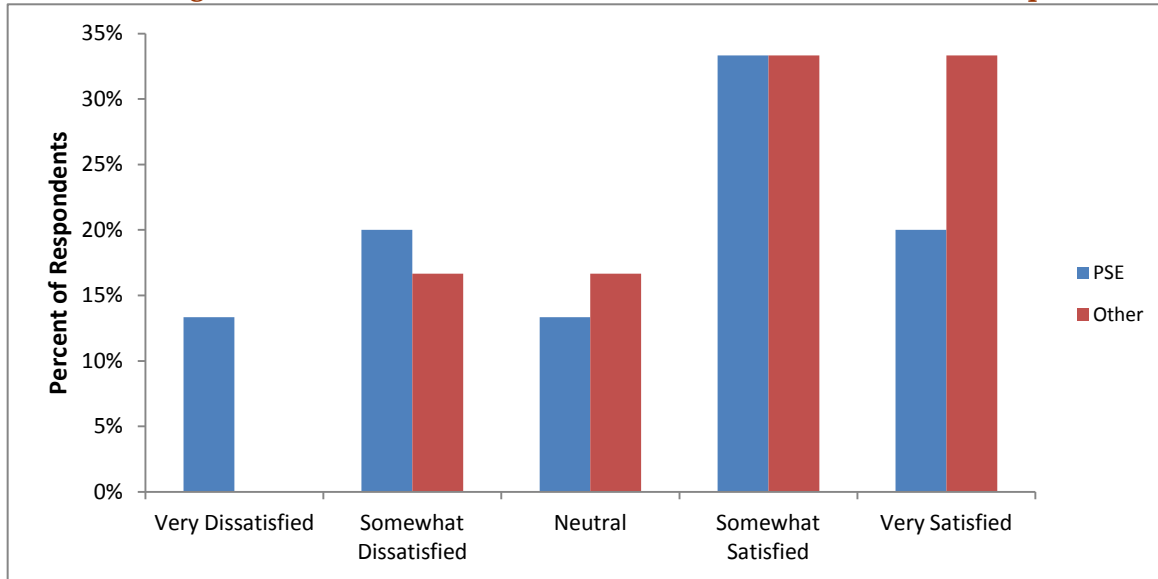
**Table 38: Who Did You Contact for Information or Assistance?**

	Participants		Dropouts		Total	
	Count	% of Total	Count	% of Total	Count	% of Total
Puget Sound Energy	13	52%	2	50%	15	52%
Converge	2	8%	0	0%	2	7%
Not Sure	10	40%	2	50%	12	41%
<b>Total</b>	<b>25</b>	<b>100%</b>	<b>4</b>	<b>100%</b>	<b>29</b>	<b>100%</b>

Source: EMI Analysis

Figure 41 shows that most survey respondents who contacted someone for additional information or assistance were somewhat or very satisfied with the response they received. However, 24% of respondents were dissatisfied with the response they received, and most of these had contacted Puget Sound Energy (33% versus 17% for Other).

**Figure 41: Customer Satisfaction with Service or Information Request**



Source:

Source: EMI Analysis

In general, respondents indicated that their dissatisfaction resulted from questions not being answered (3) or not being resolved in a timely manner (3). Interestingly, all of the respondents who were dissatisfied with the response they received had heating systems enrolled in the pilot.

### Reasons for Leaving DR Pilot Program

Notably, while two of the seven dropouts who responded to the survey noted that the cycling actually led to increases in their electricity usage and power bills, none of the dropouts cited difficulties dealing with the cycling (lack of hot water, heat, or cool air) as their reason for stopping participation in the pilot. Four of the seven dropouts who responded noted various technical issues, most related to the Digital Gateway. These included: 1) difficulty with his or her wireless Internet connection after installation; 2) problems with a computer shutting down; 3) a loud noise from the installed hardware, and 4) equipment never worked and he or she had to pay to have a contractor come out to fix it. Another one of the seven dropouts was frustrated with the lack of customer service contacts available after usual working hours.

### Incentive Level

Most participants (86%) thought that the annual incentive of \$50 was enough to compensate them for participating in the program. For those who felt the incentive should be higher, two said that no amount would be high enough to compensate them for their participation. Five

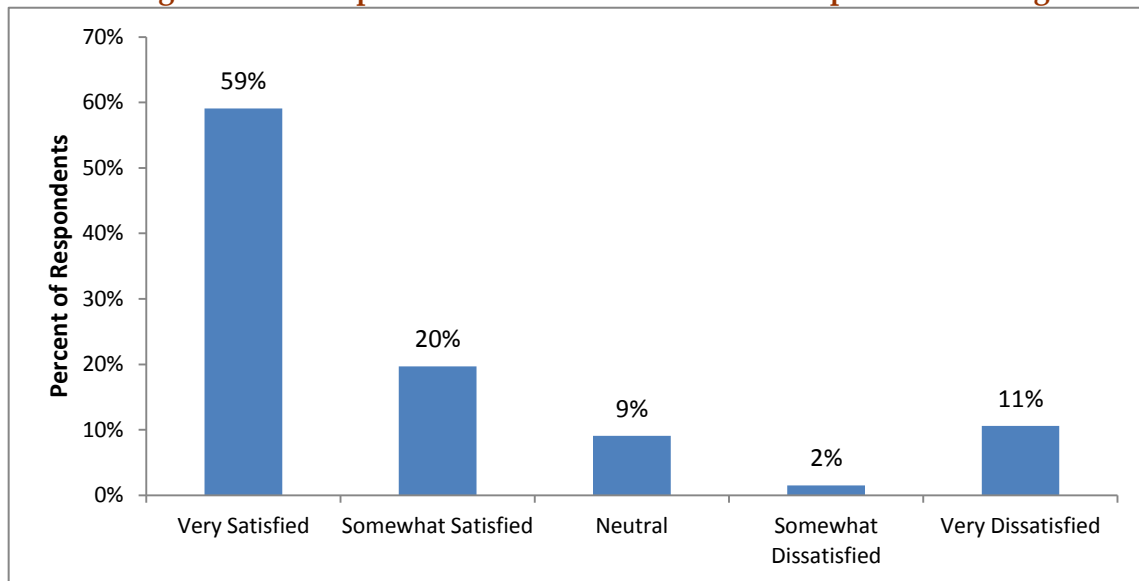


participants reported what they consider to be satisfactory incentive amounts: \$100 (2), \$150 (1), \$200 (1), and \$500 (1).

### Overall Satisfaction with Program

Overall program satisfaction was high, with more than three-quarters of participants (79%) either somewhat or very satisfied with the Demand Response Pilot program; only 12% reported being somewhat or very dissatisfied (see Figure 42).<sup>18</sup>

**Figure 42: Participant Satisfaction with Demand Response Pilot Program**



Source:

EMI Analysis

Dissatisfaction with the program overall was due to a lack of sufficient communication about the program (3), an increase in electricity bills (2), a lack of control (1), the belief that the program was a waste of resources (1), and the belief that the program led to an outage (1). A few responses, quoted below, offer additional customer perspectives:

- *“I think we have gotten no feedback, one way or the other, very little communication, few ways to give feedback...”*

<sup>18</sup> Ten respondents who answered “No” or “Don’t know” to both having water heater enrolled and having heater enrolled are included in this chart; all ten were somewhat or very satisfied. With these ten removed, a slightly lower percentage (77%) of participants report satisfaction and a higher percentage (14%) report dissatisfaction.

- *“My bills are going up instead of down, so I don’t see the purpose of this project. Trying to program the thermostat online is complicated and frustrating.”*
- *“They spent 1.6 million dollars for less than 700 households. The demand response was meant for summertime air-conditioning. Here there are only a few times a year where they need to turn on the demand response, and it was an interesting project, but I feel that it was a waste of money...”*

Along with satisfaction comes interest in continuing with the program. More than three-quarters (79%) of participant respondents indicated they would remain a participant if the program were offered after the pilot was over, and 80% stated they would recommend the program to a friend, neighbor, or coworker.

Participants who said they would not recommend the program to a friend, neighbor, or coworker cited various reasons including the program not working as intended (4), problems with the programmable thermostat (2), inconvenience (1), bill surge (1), and lack of satisfaction (1). These responses point to a need for additional communication with participants about how the program is working and for technical improvements.

## **6.2.8 Summary & Recommendations**

Overall, participants were satisfied with the program design, enrollment, and the incentive offered to them. No great discomfort was noted during the cycling events, although not all participants recalled their enrolled equipment ever being cycled in the program. Discontent, where it was noted, tended to be rooted in lack of communication or technological issues.

### **Marketing and Education**

In general, few respondents had a clear understanding of what “demand response” meant. In the future, it may be useful to create additional materials or revise the existing educational and marketing materials to explain in detail the demand response concept and the reasons PSE would offer such a program. Also worth emphasizing is that while the greatest proportion of both participants and non-participants recalled hearing about the program through a news story, *none* of the dropouts provided this response. This suggests that a news story could provide a more comprehensive understanding of demand response, which was not achieved by program dropouts. While this evidence is only anecdotal, it is clear that news media provide a widespread and potentially informative means of building customer familiarity with a program.

## **Installation**

Installation contractors should provide a realistic estimate of the time required for installation. Different equipment and configurations appeared to affect both the complexity and the length of time taken to install the control devices and digital gateway. Requesting more information about equipment and setup or conducting a separate scoping visit prior to installation might manage expectations on the part of the installation contractor and the participant.

Contractors might also spend more time training customers on the operation of their new equipment or, at the very least, ensure that the customer receives and understands the operations manuals to avoid leaving people without a means to operate their new equipment. Care should be taken to ensure that work areas within homes are left in the same condition in which they are found and that proper expectations are set regarding appearance prior to installation occurring.

## **Technology**

Technology failures and complexity appeared to be at the heart of most peoples' dissatisfaction with the Demand Response Pilot. Three technologies in particular can be highlighted as troublesome to some participants: Digital Gateway, programmable thermostat, and the website.

### **Digital Gateway**

Some respondents cited the gateway as leading to loss of Internet connections and computer shutdowns. Notably, these and other technical inconveniences were mentioned most by the dropouts. Future demand response programs may benefit from alternative technology that does not interfere with participants' Internet connections and can be maintained without disturbing the participant.

### **Programmable Thermostats**

The programmable thermostat was difficult to use, did not have the features that participants desired, and was recalled during the pilot as a potential fire hazard. Some participants noted that the thermostat was of lower quality than the one they had installed before participating and that they could not easily program the thermostat or identify desired features. The recall of the programmable thermostat for safety reasons was particularly troubling to participants. Although Puget Sound Energy responded immediately to protect the welfare of participants by recommending removal of batteries to reduce the risk of fire, participants remained uneasy about the safety of the programmable thermostat. These responses suggest that any future implementation of a demand response program may benefit from the use of a different programmable thermostat, one that is easier to use and feature-rich. In addition, PSE may want

to revise the manual, or consider additional training that ensures contractors spend time training customers on the operation of their new thermostat.

## **Website**

The website was difficult to use for many respondents, and login or password issues were particularly upsetting. If the website is meant to be a key feature of the program, allowing participants more information about their energy use and ease of programming their heating or cooling system, it should be *visually appealing and intuitive to use*.

## **Communications**

Participants would benefit from a single point of contact to minimize confusion. Participants would also benefit from a *24-hour trouble hotline* to give them peace of mind and ensure a prompt response to their difficulties.

In addition, participants showed interest in the program in general. They wanted to know more about the program while participating. Perhaps future versions of the website for participants could show how demand response participants avoid overdrawing at any one substation. For Bainbridge Island residents who already have access to the RePower Bainbridge information, connecting the dots between their efforts and the substation graphics may be sufficient.

## **6.3 Focus Group Results**

On June 14, 2011, EMI conducted two focus group sessions on Bainbridge Island. The first focus group consisted of individuals who were actively participating in the Puget Sound Energy (PSE) Demand Response Pilot Program. The second group consisted of individuals who had initially joined the program and have since ended their participation. EMI closely reviewed the transcripts, video, and notes from observation as the core components of our analysis to understand what PSE customers think about the demand response pilot program. In this section we discuss the primary findings as they relate to each of the study objectives and the implications that may influence future demand response programs. The primary objectives common to both focus groups were the following:

1. Determine how participants interpret PSE's marketing materials and efforts.
2. Document participants' motivations for enrolling in the program.
3. Characterize participants' understanding of, and experiences with, the PSE demand response pilot program.
4. Document potential concerns and potential barriers to program success.
5. Identify areas for improvement in the program.

For the focus group of individuals who had initially joined the program and have since ended their participation an additional objective was explored:

6. Document reasons why participants discontinued participation in the program.

### 6.3.1 Marketing Materials and Efforts

Objective: *Determine how participants interpret PSE's marketing materials and efforts.*

#### Overview

The moderator started each of the two sessions by asking if anyone in the group had been to a focus group before. Across the group of participants, there was only one individual who had participated in a focus group before, commenting that it was “in Seattle where they had mirrors.” The facilitator explained that in traditional focus group facilities there is typically a one-way mirror behind which observers would not be visible. On Bainbridge Island, the format of the focus group sessions was slightly different and the observers were in the same room as the participants. This arrangement could have possibly compromised the quality of the discussion among the participants, but the presence of the observers did not seem to greatly detract from, and may have actually improved some aspects of, the focus group discussions.

Once the structure of the sessions had been covered, the moderator asked a few questions about how the participants had heard about the PSE Demand Response Pilot Program. There was a broad range of answers including: electric bill inserts, newspaper articles, letter from PSE, public booth at the 4<sup>th</sup> of July celebration, advertisements on the ferry, and through the Bainbridge Energy Challenge group. Next, the moderator asked the group if they recognized any of the following marketing materials and proceeded to hold up each item one at a time. The bill insert, brochure, and ferry advertisement were fairly well recognized across the two groups, but the participants most strongly identified with the personalized letter. Specifically, comments about the letter included “Yeah, the letter was good” and “The main thing in the letter is that it gave me a phone number to call if I wanted more information.”

#### Preferences

Researchers were also interested in gaining a better understanding of how participants preferred to receive information from PSE. Participants across both groups indicated that the personalized mailings, those addressed “to customer's name” instead of a general “to resident” were much more likely to be read and valued. Participants also widely agreed that phone calls should not be used as a means of marketing. Finally, it was apparent in the discussions that seeing a combination of marketing pieces with a consistent message was much more impactful than any piece by itself.

### 6.3.2 Motivations for Participating and Purpose of Program

Objective: *Document participants' motivations for enrolling in the program.*

#### **Motivations for Participating in the Program**

Focusing on motivations for involvement in the program is useful for informing the value propositions that will be most effective at promoting future demand response programs at PSE. To this end, participants took part in a card-sort activity designed to help the researchers better understand which motivating factors were most integral to the decision to participate in PSE's Demand Response Program. For this activity, the participants were given a set of 10 cards, each with a different reason for participating in the program written on it, and were asked to pick the four most salient motivators and then rank the key motivators from most influential to least influential. The complete set of motivations for participating in the PSE Demand Response Program listed on the cards included:

- Save money on bill
- Incentive payment for participating
- Help the environment
- Use less energy
- Take control of your electric use
- Take an active role in energy conservation
- Be a part of a community initiative
- Better understand your energy use
- Reduce carbon footprint
- Help reduce the need for another substation on Bainbridge

Findings from the card sort activity indicate that there are a wide variety of reasons for why customers chose to participate in the program, with each of the ten motivations being selected at least once. There were however, several motivations for participating that were much more prevalent. Table 39 presents the top three most selected reasons that appeared across both focus groups.<sup>19</sup> What this highlights is just how strongly participants value taking an active role in energy conservation.

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<sup>19</sup> The complete set of individual rankings for all participants is provided in the appendices accompanying this report in a separate document.

**Table 39: Top Motivations for Participating in the Program**

Motivations Shared Across All Participants	Percent Response
Take an active role in energy conservation	20%
Help reduce the need for another substation on Bainbridge	14%
Help the environment	13%

*Source: EMI Analysis*

In addition to the card sort activity, each of the focus groups spent some time discussing motivations for participating in the program. As would be expected, many of the comments mirrored reasons identified in the card sort.

“... I really saw this as a chance to do just a mite in favor of environmental, global warming causes,” and

“... But it was as much to, I guess, you know, being up there to educate myself a little bit and also to help with the immediate need of not trying to build another substation on the island...”

Surprisingly, there actually was little discussion directly related to the most selected card sort motivation - “Take an active role in energy conservation.” Analysis of the card sort activity also made apparent that there are some motivations for participating in the program that were not consistent across the focus groups.

One motivating factor that varied in importance between the two focus groups during the card sort was the potential to “Save money on energy bills.” As one participant explained during the discussion, “... I’m here to reduce my energy bill. I’m here to determine whether my behavior every day affects how much energy I’m using, which affects my bill. So, if I can change my behavior, change the products I have, reduce my energy costs, reduce the amount of energy I use, I reduce my bill...” Five out of the seven participants who had left the program selected “Save money on bill” as a factor for participation, while only one active program participant selected this motivator.

Another instance where there was a difference in the card sort results between the two focus groups was for “Reduce carbon footprint.” Three active program participants selected “reduce carbon footprint” as a reason where only one participant from the group of individuals who are no longer active in the program selected this motivator. “Let’s see. Reduce carbon footprint was

my number one reason. It's just kind of a lifestyle. I drive a small car, I ride my bike whenever I can or walk. My husband commutes on his bike, as well. It's just kind of a goal at our home. Let's see, which also is using less energy..."

The facilitator also questioned the two focus groups about the role that the financial incentive had in motivating involvement. Interestingly, in the card sort activity, only active participants chose the incentive payment for participating as one of their top four motivators. In the group discussion though, the majority of participants across both focus groups tended to agree that the fifty-dollar incentive offered by PSE was a contributing factor to signing up for the program. Comments offered by participants included: "I think the fifty dollars definitely persuaded us," "It was a motivator for us. Oh yeah, definitely," and "It just seemed like it was easy fifty bucks to me." Not all participants though viewed the financial incentive as a significant motivator for joining the program. "The fifty dollars was no motivator. I was going to do it anyways," and "No, no fifty dollars a year isn't much incentive."

### **Perceived Purpose of the Program**

The focus groups were also able to provide a better understanding of what PSE customers on Bainbridge Island perceived the primary purpose of the demand response program to be. The participants generally agreed that the purpose of program was to avoid the need to build a new substation on the island. Several comments that illustrate this view include: "I thought the basic idea was to avoid a substation on the island. I mean that was what really caught my attention, the letters about that in the paper", "No new substations, no new transmission lines," and "Not having to build additional facilities." There were also several other participants in the focus groups who saw saving money as the purpose of the program. "Saving money, essentially. You know, if they have to build that, it's going to cost us more money on our electrical bills," and "I was going to say initially I thought it was we were going to save money, on our [home] energy bills."

### **Reservations to Joining the Program**

Along with expressing an understanding about the purpose and the benefits of the demand response program, participants also shared some of their initial reservations about joining. One of the most common reservations expressed by participants was the concern over potentially losing control of heating decisions, especially on cold days. Other reasons provided included concerns over not having enough hot water during curtailment events and concerns over the impact the program may have with personal equipment like computers and thermostats. Sample comments from the participants on these topics include:



*Running out of resources: "I was afraid we were going to run out of hot water."*

*Control over heating: "Well, I think you don't like the idea that you're going to lose control over something like heating your home."*

*Technology reservations: "... I was more concerned that they were going to mess up the computer or they're going to screw up the thermostat..."*

### **6.3.3 Experiences with the Program**

Objectives: *Characterize participants' understanding of and experiences with the PSE demand response pilot program and Document reasons why participants discontinued participation in the program*

#### **Impact on Demand Days**

The discussion of impacts on actual demand days for participants in the program resulted in a broad range of experiences identified. For some, the events seemed to pass by almost unnoticed, while for others the experience brought on considerable inconveniences. In most cases, the responses from participants across the two focus groups were surprisingly similar.

*"... I only remember one time when I saw the light and didn't feel any effect of that..."*

*"I saw a red light and I said, 'Okay, there's something going on.' The day to day operations in our house, we didn't even notice it."*

Other experiences by participants highlighted the impact that variations in each home's ability to retain heat have on individual experiences. *"Yeah, we had a very different experience because we barely noticed anything. I mean our house keeps the heat in well."*

In addition, some participants were able to offset the impacts of curtailment events with alternative heating sources. *"No. Well, I have two fireplaces so I guess if it's chilly in the house I just ... flip one or two of them on and the house is always warm"*

One experience that actually varied across participants in the program is the extent to which hot water tank supply met the needs of the family during curtailment events.

*"We just noticed that the hot water ran out in the shower really quickly during one period of time"*

*"We never ran out of hot water. And I've got three daughters constantly doing laundry, showering, everything."*

The most widely shared experiences discussed across both of the two focus groups dealt with the impacts of the curtailment events on cold weather days. For some customers, there was a significant cost and inconvenience to participating in the program.

“It was cold. And I had to put my boots on and my coat.”

“Yeah, it wasn’t just one event, there was lots of events and it was very dramatic and I just thought why am I doing this? Everyone else is sitting in nice warm houses and I’m sitting here in a freezing.”

“Yeah, we noticed it a lot. We kept seeing that red light come on and there would be snow on the ground and we’d be sitting in our house freezing. Yeah, I just thought it was worth it.”

“We noticed that we were cold but I mean and it stayed around 65. That just wasn’t warm enough for us but it would stay that way and it would go on and then the auxiliary heat would come on right away with it when it finally came back on...”

## **Equipment and Thermostat Issues**

As participants in the focus groups shared their experiences with the program, equipment issues became a significant topic of discussion. One significant technical challenge appeared to be how controlling the thermostat on demand days impacted the effective operation of heat pumps for participants. During the discussion, several participants commented that after events the auxiliary power supply system would have to cycle on in order to help the heat pump catch up with heating demands.

“Well, as I understood it, the thermostat should have, I mean the way when we had our thermostat, our heat pump installed some 20 years ago they said that it sort of ran the thing a little bit in the middle of the night to see how much power it would take to raise it like one degree. Then it would program it to begin in the morning so it would come up very slowly so that your auxiliary heat would not come on.”

Contributing to this was that “It controlled the set point on your thermostat but it did not control the auxiliary power part. To me that’s a bad design.” Another focus group participant added “But then those kinds of considerations did not appear to be present in the design of the program. As a result, several of these customers experienced considerably larger power bills than they had in the prior years. This point was expressed by one participant who explained, “We noticed that we were cold but I mean it stayed around 65. That just wasn’t warm enough for us but it would stay that way and it would go on and then the auxiliary heat would come on right away with it when it finally came back on... It just didn’t make sense to be on the program

because I could see we were actually using more power.” Another also experiencing a similar situation added, “Yeah, that’d be important. I think this thermostat in my program it apparently kicked on to emergency power just by itself. So that was the explanation for my hugely increased bill.” This issue, discussed by participants, ended up as one of the reasons for leaving the program.

The one piece of equipment across both focus groups that seemed to attract the most discussion was the thermostat. Many expressed issues ranging from concerns about the safety of the thermostat installed to challenges they experienced operating it. Examples of these issues are detailed below.

*Internet safety concerns:* “I think one thing that needs to be studied, and I’m not an expert on this in any way, but my son is in internet security and I think there needs to be further research on the connection between that little box and your internet connection. It could potentially be something that could be hacked into.”

*Difficulty operating:* “... I just was not able to operate with the thermostat I got from the program ...”; “It was not intuitive to figure out how it worked”; “Even with the manual it was difficult”; and “Well, I got a computer and I’m basically illiterate with a computer but I can email and do things like that. If I’m told that I can go on the internet and program my computer I wouldn’t even attempt it because I can’t deal with that thermostat anyway. It’s so complicated and I just wouldn’t try it.”

*Programming issues related to battery removal:* “Well, we had to figure out how to program it but, of course, once the batteries were out every time there was a glitch in the power you lost it all and that sort of thing and so you had to reprogram it all again”

*Challenges with clock:* “The only thing with the thermostat that I have is there was no way that I could figure out how to adjust the time on it... sometimes it would be a half an hour off and I had no control over the time on mine.”

*Safety and Installation issues:* “And the idea that the batteries have to come out and it could’ve caught on fire did not appeal to me at all, or that it took three visits to get the whole system going”

## **Customer Service Experiences**

In addition to challenges presented by equipment issues, participants also expressed concerns about both the availability and quality of customer service. One significant source of frustration appears to be due to the portion of the program that was contracted out to a vendor. Several

topics mentioned by focus group participants include lack of knowledge by support staff, limited experience with heating, and difficulty getting assistance from technicians.

*Lack of knowledge:* “Because they always gave you this other number to call and Puget Power didn’t know anything, didn’t anything about half of it”; and “... I started calling Puget Power and like you, I got some people who it sounded like they had just graduated the day before and were clueless, nice people, well meaning, but ineffective.”

*Minimal experience:* “[Their] experience was on the east coast where the big power user is air conditioner and they were familiar that that situation, and the situation in Bainbridge is different [and] outside their immediate experience base”

*Difficulty contacting technicians:* “They were contacting somebody local as a technician who would actually come out to the house and fix things and that was when I called that was the fellow that was out of town at the time.”

The customer service issue that appeared to be shared by many of the participants was challenges with installation of the equipment necessary for the program.

“... I don’t think I had good customer support from the beginning. I had two men who came in and did things. They didn’t talk to me much. They handed me two sheets of paper or three and left.”

“It was just, people, one technician would arrive and he didn’t have the right part. Another technician would arrive and he didn’t know how to do it. A third technician would arrive and something’s still, you know, and eventually it got hooked up but it took at least three visits. And it just didn’t seem to be very well-planned.”

“... A subcontractor came in to install the system and the letter said it would take about 40 minutes to do it. This guy took about four hours and in the process blew a fuse and I had to go to Ace hardware to get a fuse for him. So I think he was maybe first time installing one of these things. So that was a little, kind of a rocky start.”

## Reasons for Discontinuing Involvement

The second focus group session of the evening was with PSE customers who had initially been involved in the program, but had cancelled their participation at some point in the process. The discussions with this focus group highlighted the broad range of reasons why participants terminated their involvement in the program. As mentioned earlier, one of the reasons was a the increased energy usage and resulting power bills due to auxiliary power supply cycling on after curtailment events. Another common reason why participants did end up leaving was a result of personal discomfort from the lack of available heat on demand days.

“That’s why I’m not on the program anymore. I got up and it was 50 degrees in my house and we didn’t have heating for about three hours and I just thought, no amount of money is worth this.”

One of the most interesting findings is that many of the other participants who left did so for reasons unrelated to experiences during curtailment events. Examples provided include: safety concerns, technical issues with equipment, and increased bills.

*Thermostat safety concerns:* “So I think the thermostat is also another reason we came off the program. I mean to get a letter in the mail saying your thermostat is dangerous, take the batteries out. I mean I was expecting a phone call saying we’re coming to take the thermostat out and put a better one in.”

*Thermostat operation issues:* “... I just was not able to operate with the thermostat I got from the program. That’s why I dropped out.”

*Technical issues:* “... My modem, my router kind of went haywire so I had to replace it. I did not have two Ethernet ports on it so they could not hook me back in. So this is all ... Its more of a technical thing and the glitch happened just before the battery issue. So I didn’t participate in that either. Anyway, when they took the thermostat out with my termination, I put my old one back in and it worked just fine.”

*High bills:* “I didn’t feel any event at our house but our heating bill went up dramatically. So after about six months, I called them up and said come get it. This is not working.”

### 6.3.4 Potential Barriers to Program Success

Objective: *Document potential concerns and potential barriers to program success.*

One of the important topics discussed in the focus groups were barriers to the program’s future success. The participants were very open and forthright about their concerns. One barrier to

success that was shared by several participants and discussed for some time during the sessions dealt with the aesthetics of the equipment installed as part of the program. The concerns included both how the equipment looked and where it had to be placed. The participant comments shown below on the aesthetics of the equipment also offer insight in to the difficulties presented by the large variety of ways homes are structured.

“Where they put the water heater thing because it’s right in my back door entry and it’s the most ugly looking thing you’ve ever seen.”

“Yeah, they cut up all my sheetrock and stuck it out there and it’s just like ... and I’m hoping they repair it when they take it out. I mean, they didn’t have much choice because our water heater is in the closet and backed up against the wall. So they had put it in right next to the electrical box, which is right in the entry and you have this big, gray, ugly thing sticking up there”

Several other aspects also mentioned as barriers to the program’s success were fairly similar to the reservations mentioned previously. Two very specific examples include concerns over the ability to control the heating and issues with the technology required as part of the program. The responses below from the discussions highlight these points.

*Control over heating:* “I think when you asked for our barrier and why people wouldn’t participate, I think there’s a control issue as far as people like to control their environment and that is only natural.”

*Technology concerns:* “Some people do object to the Wi-Fi being put in their house. I’ve had some friends of mine that say, yeah, they don’t want more Wi-Fi.”

### **6.3.5 Areas for Improvement**

Objective: *Identify areas for improvement in the program.*

#### **Areas for Improvement**

When provided an opportunity during the focus groups to share thoughts on the ways PSE could improve the program, the participants across both groups responded without any reservations. There were a wide variety of recommendations offered, but all tended to be very tangible and actionable items. The areas for improvement offered by the participants can be summarized into the following themes:

- Offer education about the importance of energy efficiency and conservation
- Improve education about the program benefits and processes

- Deliver better customer support for the program with knowledgeable staff
- Provide customers with higher quality equipment (thermostats)

Of the four themes, education was one of the most widely discussed areas for improvement. One participant phrased it, “I think trying to help people understand what the purpose of it is in terms of, you know, I would consider maybe another metaphor that some people might get, which it’s a governor on your electrical use maybe? Something to limit the use ... and so it’s a matter of helping to educate the entire community on what the purpose of it is.”

The other area for improvement that was broadly agreed upon by participants to be important was the need for timely and knowledgeable customer support. An example of one such comment offered “... But, yeah, I’d say the people; they need to work on the people. The people who install, the people who support the program; there should have been somebody that you could call, a central desk, if you had a problem and that person sorted it out. That would have been good.”

## **What PSE Could Have Done Differently**

When participants in the second focus group, consisting of customers who left the program, were specifically questioned about how PSE could have responded differently and what could have changed their mind about leaving the program, several possibilities were offered.

*A letter of explanation:* “Yeah, [if] I got a letter that said they were sorry and they had done these fixes and so on. I’d be back on instantly.”

*Change in thermostat was echoed by many:* “They could have put a different thermostat in,” “Invest in decent thermostats,” and “Would I do it again? Yeah, I would. I agree. If I was assured that the thermostat would work and the associated gear would work and when I called to talk to somebody about it I’d get somebody who could talk and knew what was going on.” Another participant also followed up with “And that it worked properly with the heat pump.”

*Better customer service:* "... The people who install, the people who support the program, there should have been somebody that you could call a central desk if you had a problem and that person sorted it out. That would have been good," and "We had, really for us it wasn't really a problem other than our heating bill went way up. If there was some way they could fix that or do something better or have better service."

### **6.3.6 Summary of Focus Group Findings**

In reviewing the focus group transcripts and notes, it appears that the overall participant experience has been positive. The participants saw the program as both valuable and necessary, especially if Bainbridge Island is to avoid the building of additional substation facilities. In addition, they tended to all see proactive energy conservation efforts as extremely worthwhile. Even many of those individuals who left the program commented that if the areas for improvement were addressed, they would likely participate in the program again.

In addition, participants from both focus groups also expressed interest in wanting to know the effectiveness of the pilot program. One participant in the first focus group questioned, "... Is [the program] going to be expanded if it's a success to the whole island so that it can really have an impact? An individual in the second focus group also asked a similar question, "Do we get a final report on the program and [if] it worked in Bainbridge?"

A representative from PSE answered, "That's a long answer. The pilot is being evaluated right now, both from a process standpoint which this meeting tonight involves as an analytical or quantitative component... We have had modest success at best... I think the strategy will be to take this experience ... and implement it at a later time when we have better technology and lower cost technology to make it easier for people to participate. This was definitely a learning experience for all of us. And what each of you contributed is very valuable in terms of learning how we would want to do this on a larger scale."

One participant questioned the number of participants PSE wanted, "... We didn't have as many people as [PSE] wanted to make it effective. How many more people did they need?" Responding was a representative from PSE, "I think we had room for 700, or that was about what we were hoping for and I think we had 6,700 customers that we targeted with mailings and the various ads and that sort of thing... And we topped out around 540." The participant responded back, "I'm really surprised to see [that] because I thought that Bainbridge was more of a conservative conservation type of community."



Understanding the experiences and the perceptions of the participants in the PSE Demand Response Pilot Program can provide valuable insights for PSE's program design team. In addition to sharing what was found valuable about the program, participants also offered their recommendations for areas of improvement. Detailed below are lessons learned for PSE to consider when 1) determining whether to expand the pilot program and 2) designing future programs.

- ***Closing the Loop:*** During the focus group sessions, participants expressed interest in knowing the outcome of the pilot program and if PSE plans to expand the program. Given this interest, PSE may want to consider a communication following the conclusion of the program that addresses these points.
- ***Improved Technology:*** A significant theme across both focus groups was that high quality equipment is extremely important to customers. In addition, they also expressed the need for it to be user friendly. This view was highlighted in the participants' experiences with the thermostat operations and online program. PSE may want to consider how these concerns can be addressed in future program designs.
- ***Importance of Customer Service:*** Another area emphasized through the focus group discussions is the value placed on customer service. One of the findings was that customer service provided in the program was at times inconsistent. In addition, participants very much seemed to view the call-center as a separate entity from PSE. A takeaway from these findings is for PSE to be aware of the impact that contractors being viewed as either internal or external to PSE may have on customers' overall experience and perception of a program. It may be important in the future for PSE to carefully consider if they want third party contractors to brand themselves as PSE partners or as separate entities.
- ***Clarifying the Money Saving Value Proposition:*** The findings indicate that a large majority of participants expected to save money on their energy bill through participation in this program. Although marketing materials never directly mentioned saving money, individuals in the program assumed that reduced energy usage during curtailment events would result in a corresponding reduction on their bills. Participants who ceased their participation in the program seemed to indicate that when saving money as a result of participation in the program did not materialize they chose to drop out of the program. PSE may want to consider how to clear up confusion around this value proposition in the future.
- ***Increased Education:*** One of the major themes that came out of the focus groups was the suggestion for PSE to expand education on energy efficiency and conservation.

Specifically commented was that an educational campaign may be a possible option to influencing behavioral change. One comment addressing this view was, "... Why doesn't PSE, instead of having something installed in the people's homes ... just educate the public and say, 'Hey, don't do your laundry at 8:00 in the morning. Don't have your thermostat spike and not spike. Run your dishwasher at 10:00 at night instead of right after dinner hour.'"

- ***Time-of-Day Use Study:*** Related to further educating the public on ways to avoid early morning and evening energy spikes, participants also discussed the possibility of PSE exploring time-of-day use rates again. In order to better understand if this is an option that PSE would want to consider again, a time-of-day use study could be implemented to further explore the potential benefits and also consequences of such a program. One participant phrased this view as, "I mean, can they change the price of electricity? So many other areas of the country for that peak rate, 6:00 to 9:00 in the morning, they double the rates or something. And people will learn very quickly, I don't want to burden electricity at this time." Like this PSE customer, other participants in the focus groups seemed very open to the idea. Like any new program though, a pilot study would be necessary to truly assess if it is practical option for PSE to consider as a means to help meet load growth and peak concerns.

## Section 7. Conclusions and Recommendations

Two of the principal purposes of a pilot program are to demonstrate measurable program impacts and to produce information – “actionable intelligence” – which may be used to guide future program roll-outs. The PSE Residential Demand Response Pilot not only demonstrated significant reductions in demand, but also produced a considerable body of practical information from which to base future investment decisions regarding a DR program.

### 7.1 Conclusions

The pilot was successful in that it produced detailed estimates of load reductions by device type. In the winter season, these impacts averaged approximately 0.7 kW for water heater controls to nearly 2 kW for electric furnaces and nearly 3 kW for heat pumps. Morning events tended to produce more load reduction than did afternoon events and winter events more reduction than summer events. The pilot also raised a variety of technology and program design/implementation issues that PSE can improve upon should the company pursue a large scale rollout.

On the whole it appears that participants were satisfied with the program, with 79% of those surveyed indicating that they were very or somewhat satisfied with the program. Most participants – heat pump participants excepted – experienced little or no discomfort during curtailment events. The most significant area for improvement is in regard to the selected control technologies, as indicated both by surveyed participants and by the rate at which end-points were successfully curtailed.

Encouragingly, although most participants had trouble understanding and explaining what demand response is, many understood its ultimate purpose – to shift electricity consumption away from peak hours and thus allow for the possible deferment of the construction of additional infrastructure (the substation) on the island. That said, the two most commonly cited reasons for participating in the program by those surveyed were to use less energy and to take an active role in energy conservation. It is unclear to what degree – if any – program participation would have differed if participants had been aware that demand response programs typically realize little, if any, energy savings. A non-trivial percentage of participants also indicated that an important reason they decided to participate was to save money on their electricity bill. Typically, the bill savings provided by participation in a DR program will be negligible (without time-differentiated pricing).

Perhaps of most value to the planners of any future broader program roll-out are the robust estimates of the impacts of curtailing water heaters, heat pumps, electric furnaces and baseboard heaters. Although the demand reduction from baseboards is relatively low, and there

remain some questions regarding the impact of water heater afternoon curtailment, morning water heater curtailment impacts suggest that the demand reduction potential of these devices is greater than previously thought. Likewise, heat pumps were shown to have considerably more demand response potential than previously thought, particularly on very cold winter mornings; and electric furnaces were found to offer higher than expected and very consistent demand reductions.

## 7.2 Recommendations

This report has allocated recommendations into one of two categories: 1) those pertaining most to the results of the impact evaluation and 2) those relating to the process evaluation. There is some cross-over between the program recommendations that have come out of the impact and process analyses and the evaluation team suggests that reviewers read all recommendations. Additionally, all recommendations implicitly assume an interest on the part of PSE in developing a demand response program in the future and are intended to provide guidance, based on the lessons learned in the pilot.

### 7.2.1 Impact Evaluation Recommendations:

- **Conduct research into the root cause of the minimal DR impacts observed in the pilot from baseboard heaters.** Impacts from this end-use were found to be minimal and are certainly not cost-effective from a system stand-point. If a curtailment procedure cannot be found which more effectively reduces household demand during events, PSE should not attempt to control this end-use.
- **Limit water heater curtailment to morning-only events when a high proportion of a home's hot water is used.** If PSE wishes to call water heater control events in the afternoon, the evaluation team recommends that additional experimentation be undertaken, using data-loggers and home inspections, to assess why the afternoon curtailment of water heaters seems to result in a snapback impact greater than the DR impact.
- **Consider investigating why a disproportionate number of water heaters failed to respond to control events.** PSE should also consider what alternative technologies exist that may offer more reliable end-point control without sacrificing two-way communication.
- **Target water heaters as the least intrusive and most reliable means for achieving winter peak demand curtailments that are acceptable to customers.** Unlike curtailment of space-heating, the curtailment of water heaters during very cold winter mornings passed almost unnoticed by participants while still providing significant demand reductions when curtailed.

- **Consider offering heat pump and electric furnace customers higher incentives, or using a less aggressive cycling strategy to attain a better balance between per-device impacts and customer satisfaction/participation.** Although the largest demand impacts come from the curtailment of heat pumps and electric furnaces, customer discomfort as a result of curtailment could lead to lower participant retention rates.
- **Track non-responsive end-points on an on-going basis.** Following each event the program manager should review the list of non-responsive end-points. Technicians should be dispatched to service devices which have failed to respond to two or more consecutive end-points. The program manager should also review the technicians' reports for any patterns in the distribution of non-responsive end-points.

### 7.2.2 Process Evaluation Recommendations

- **Find improved, more customer-friendly alternatives to program technologies offered to participants.** Many participants expressed dissatisfaction with the programmable thermostat in particular, but also with the Digital Gateway and the website.
- **Work with contractors and equipment providers to determine to what degree equipment can either be camouflaged or else installed out of sight.** A frequent complaint on the part of participants was the aesthetic impact of control device installation.
- **Consider reducing the types of equipment controlled to streamline the installation process and improve participant satisfaction with that process.** Contractors responsible for device installation indicated that many of the delays and challenges at the installation stage were due to the number of different types of equipment to be installed.
- **Establish a well-advertised single point of contact with extended office hours and ensure that customer service representatives are well coached so as to be able to provide clear explanations to customers experiencing problems.** Nearly a quarter of participants that contacted a service representative regarding the pilot were dissatisfied with their experience, and in both surveys and focus groups, participants indicated that there was a significant amount of confusion regarding whom they should contact for help.
- **Update existing program materials, such as newsletters, manuals, and the website, to improve customer understanding of demand response.** Although participants seemed on the whole to grasp the end purpose of DR (shift usage, defer infrastructure investment), few could explain what it was. It is especially important for customers to understand that their participation will likely result in few, if any, energy savings and that they are unlikely to observe any noticeable bill savings as a result of participation.

# Evaluation Report Response

**Program:** Residential Demand Respond Pilot

**Program Manager:** Kim Saganski

**Study Report Name:** 2011 EM&V Report for the Residential Demand Response Pilot Program

**Report Date:** February 3, 2012

**Date ERR to Program Manager:** February 3, 2012

**Evaluation Analyst:** Navigant, Eric Brateng

**Date of ERR:** February 12, 2012

**Please describe in detail, action plans to address the study's key findings and recommendations.**

## Impact Recommendations

**Conduct research into the root cause of the minimal DR impacts observed in the pilot from baseboard heaters.** Impacts from this end-use were found to be minimal and are certainly not cost-effective from a system stand-point. If a curtailment procedure cannot be found which more effectively reduces household demand during events, PSE should not attempt to control this end-use.

### PSE Response

Minimal demand response impacts were observed in the pilot for homes in which baseboard electric or wall heaters were controlled. More research prior to introduction of this measure in any large scale program would be needed to determine if, or how, this heating type might be curtailed to effectively reduce household electric demand during control events.

**Limit water heater curtailment to morning-only events when a high proportion of a home's hot water is used.** If PSE wishes to call water heater control events in the afternoon, the evaluation team recommends that additional experimentation be undertaken, using data-loggers and home inspections, to assess why the afternoon curtailment of water heaters seems to result in a snapback impact greater than the DR impact.

### PSE Response

If afternoon curtailment is a necessary component of a future program, then PSE agrees that additional experimentation should be conducted to assess why afternoon curtailments of water heaters result in a post event snapback greater than the curtailed kW impact during a control event.

**Consider investigating why a disproportionate number of water heaters failed to respond to control events.** PSE should also consider what alternative technologies exist that may offer more reliable end-point control without sacrificing two-way communication.

### PSE Response

PSE agrees that prior to implementing a residential DR program, more research is needed to assess why so many water heaters failed to respond to control events compared to other devices in the pilot. Perhaps such an assessment would be helpful in identifying more reliable technological specifications for use in future programs

**Target water heaters as the least intrusive and most reliable means for achieving winter peak demand curtailments that are acceptable to customers.** Unlike curtailment of space-heating, the curtailment of water heaters during very cold winter mornings passed almost unnoticed by participants while still providing significant demand reductions when curtailed.

**PSE Response**

PSE agrees that curtailment of water heaters was the least intrusive and most reliable means for achieving winter peak demand curtailments that are acceptable to customers. Water heater curtailment is best in the morning.

**Consider offering heat pump and electric furnace customers higher incentives, or using a less aggressive cycling strategy to attain a better balance between per-device impacts and customer satisfaction/participation.** Although the largest demand impacts come from the curtailment of heat pumps and electric furnaces, customer discomfort as a result of curtailment could lead to lower participant retention rates.

**PSE Response**

Offering heat pump and electric furnace customers higher incentives, or using a less aggressive cycling strategy to attain a better balance between device impacts and customer satisfaction/participation could be helpful. Completing an inventory of non-electric supplementary heating sources (and their use during events) for these homes would also be important. Of all the equipment types curtailed for this pilot, the heat pumps were the most problematic with regard to complexities of their control technology and potential for creating excess operation of these systems' supplementary electric strip heat during post event recovery. Additional field testing of heat pump control strategies would be highly recommended prior to a decision to embark on a large scale enrollment of homes in a future demand response program.

Homes with central forced air electric furnaces represented a small proportion of the pilot enrollments (10%). In any future large scale program, investigation should be conducted to determine the efficacy of focused recruitment in mobile home parks where typically, a high percentage of homes are equipped with electric furnaces. However, because older vintages of these homes are typically poorly insulated, pre-enrollment assessment of potential for occupant discomfort during events could be an important initial screening step.

**Track non-responsive end-points on an on-going basis.** Following each event the program manager should review the list of non-responsive end-points. Technicians should be dispatched to service devices which have failed to respond to two or more consecutive end-points. The program manager should also review the technicians' reports for any patterns in the distribution of non-responsive end-points.

## PSE Response

Non-responsive end-points averaged 25 to 35 percent during the pilot. PSE Tracked non-responsive end-points on an on-going basis and made up to three attempts to re-engage off-line customers (via phone call, letter, email and/or site visit). Some attempts at re-engagement were successful and some were not. Reasons for devices being offline were varied and included (but were not limited to) unplugged gateways; new routers, computers or internet service providers; and improperly commissioned devices. Customers with new routers, computers or internet service providers were unable to reconnect on their own due to security protocols imbedded in the devices.

## Process Evaluation Recommendations

### **Find improved, more customer-friendly alternatives to program technologies offered to participants.**

Many participants expressed dissatisfaction with the programmable thermostat in particular, but also with the Digital Gateway and the website.

### **PSE Response**

Potential future programs are highly likely to be based on new and alternative technologies offering more reliable end-point control without sacrificing two-way communication, and more customer-friendly technologies. PSE agrees that national standards for cyber security and performance of networked devices such as load switches and communicating thermostats and compatible load management software are rapidly evolving.

**Work with contractors and equipment providers to determine to what degree equipment can either be camouflaged or else installed out of sight.** A frequent complaint on the part of participants was the aesthetic impact of control device installation. National standards for security and performance of networked devices such as load switches and communicating thermostats and compatible load management software are evolving. Over the next few years a new generation of open source demand response devices and management software will overcome many of the problems experienced during this pilot.

### **PSE Response**

PSE agrees that in the near future a new generation of open source hardware and management software is likely to overcome many of the problems experienced during this pilot. We anticipate that these new technologies will also provide compact load switches and more user-friendly communicating thermostats that will overcome the aesthetic and use issues raised by some pilot participants.

**Consider reducing the types of equipment controlled to streamline the installation process and improve participant satisfaction with that process.** Technician's responsible for device installation indicated that many of the delays and challenges at the installation stage were due to the number of different types of equipment to be installed.

### **PSE Response**

Many of the delays and challenges at the installation stage were due to the fact field technicians had to install load switches on two different types of space heat in addition to electric water heaters. They also had to exchange the homes' existing heat pump thermostats for the communicating model used in the pilot. This introduced unusual complexity requiring that technicians have substantial conventional residential electrical work experience.



The evaluation report recommended reducing the types of equipment controlled to streamline the installation process and improve participant satisfaction with that process. The process of recruiting and enrolling customers, scheduling equipment installation, securing required electrical permits, performing installation and testing, is complex and costly. The goals of effectively capturing maximum curtailable capacity at the lowest cost from each home, and minimally inconveniencing participating customers make detailed pre-planning of controlled loads, installation techniques and installer training critical for any potential future large scale program.

**Establish a well-advertised single point of contact with extended office hours and ensure that customer service representatives are well coached so as to be able to provide clear explanations to customers experiencing problems.** Nearly a quarter of participants that contacted a service representative regarding the pilot were dissatisfied with their experience, and in both surveys and focus groups, participants indicated that there was a significant amount of confusion regarding whom they should contact for help.

#### **PSE Response**

The pilot provided excellent opportunities to learn about challenges particular to customer service communications with this kind of program. Some communication issues encountered early in the program such as customers calling PSE for pilot program customer service were improved during the pilot. Customer service also improved as we learned about issues with the control devices. We agree that a future program should include establishing a well-advertised single point of contact with extended office hours. Lessons learned from this pilot will help us ensure that customer service representatives are well coached in the future to provide clear explanations to customers experiencing problems.

**Update existing program materials, such as newsletters, manuals, and the website, to improve customer understanding of demand response.** Although participants seemed on the whole to grasp the end purpose of DR (shift usage, defer infrastructure investment), few could explain what it was. It is especially important for customers to understand that their participation will likely result in few, if any, energy savings and that they are unlikely to observe any noticeable bill savings as a result of participation.

#### **PSE Response**

Availability of a dedicated website for use with pilot enrollees could bring significant efficiencies to the process of informing participants, educating, performing enrollment and scheduling tasks, transmitting updates/reminders, and management and troubleshooting. Due to staffing, budget, and time constraints, along with the small scale of the pilot, establishing a website for this pilot was not practical. For a large-scale, long-term program, it should be viewed as a necessity for effective management.

#### **Other Lessons Learned by PSE**

The purpose of the pilot was to maximize the utility's demand response learning experience with multiple electric space heat types in addition to controlling electric water heaters. During the RFP process, this limited the number of qualified bidders who could provide both communicating thermostats and load switches. Several bidders submitted proposals that provided thermostats for heat pump and electric furnace participation, but did not offer electric water heater or baseboard heat control. Several RFP respondents were firms with innovative software proposals but lacked hardware availability that had seen field use in utility-scale programs.