Pilot Study for a Thermostatic Shower Restriction Valve

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ABSTRACT

The ShowerStart device is a thermostatic valve installed in line with the user's showerhead that is designed to reduce hot water and energy waste by shortening the time that hot water is left running before the user steps into the shower. Many users multi-task while waiting for their showers to reach bathing temperature; wasting hot water if the shower reaches bathing temperature and remains unoccupied. The device cuts the flow of hot water to a trickle until the user enters the shower and pulls a cord to restart the full flow of hot water. In this 2014 pilot study of ShowerStart devices, Pennsylvania Power and Light (PPL Electric), located in central and eastern Pennsylvania, worked with Cadmus to answer two questions: (1) how much energy does the ShowerStart™ device save users and (2) what kind of experience do these users have when showering with the device?

Cadmus metered 22 showers for one month and fielded 18 satisfaction surveys with the participants in the pilot study. We found that a ShowerStart device installed in a single-family home with an electric water heater saves on average 121 kWh per year: in the context of other hot water measures in the Pennsylvania Technical Reference Manual (PA TRM), this represents less savings than a low flow showerhead or a kitchen faucet aerator, and more savings than a bathroom faucet aerator. The surveys showed that many participants were satisfied with the device and said it was easy to use. Three of the 18 participants reported malfunctions or were dissatisfied with specific aspects of their experience, citing issues that may be addressed with user education and screening.

Thus, the pilot study found that the ShowerStart device achieves savings, and satisfied many of the users, while about a quarter of the users were less than very satisfied overall. These conclusions suggest that this measure can offer savings for residential programs, and also requires some level of education to avoid dissatisfied participants.

Introduction

In the fall of 2014, PPL Electric and Cadmus conducted a pilot study of ShowerStart, a thermostatic shower restriction valve. The device restricts the shower's hot water from flowing down the drain and being wasted while the user waits for the water to warm to bathing temperature.

Cadmus and PPL Electric had previously collaborated on developing an interim measure protocol (IMP) for the 2015 PA TRM. The IMP provided the method to quantify deemed savings for thermostatic shower restriction valves, but it had relied on estimates for several input values, especially for the duration that the device would be engaged and the temperature of the water that it would prevent from being wasted. PPL Electric initiated the pilot study and asked Cadmus to collect data to support or revise these estimates and to evaluate the functionality and usability of the device for inclusion in its programs.

Objectives

The primary objectives of PPL Electric's ShowerStart pilot study were to:

- Test the product's functionality and usability
- Collect data to support the input values in the 2015 PA TRM
- Evaluate energy savings
- Assess user satisfaction

We discuss the design, methods, results and conclusions for this study in the sections below.

Study Design and Methods

Overall Design

The study employed two activities to achieve its objectives: water flow/temperature metering and a participant satisfaction survey. The approach used to measure each of the study's objectives is described in Table 1.

Table 1. Objectives and Measurement Methods

Study Objective	Measurement Method
Product functionality and usability	Water flow/temperature metering and participant satisfaction survey
Data to Support PA TRM Values	Water flow/temperature metering
Energy savings	Water flow/temperature metering
User satisfaction	Participant satisfaction survey

Due to time and budget constraints, the pilot study measurements relied only on post-installation metering of shower water flow/temperature, rather than measuring flow and temperature both before and after installation. Participation in the pilot study and the installation of the ShowerStart device may have caused some participants to change their behavior post-installation. For example, the participants may have started to set the shower water temperature differently, or they may have changed total showering time. To determine whether the post-installation metering results reasonably represented the pre-installation values, we included questions in a satisfaction survey to determine if participants changed their behavior during the pilot study.

Study Recruitment, Sample, Duration, and Steps

PPL Electric recruited participants for the study by e-mailing current PPL Electric employees a short participation form. Participants qualified for the study if they lived in the PPL Electric service territory, lived in a home with at least one regularly used shower, and used an electric water heater. The participants agreed to let us install a ShowerStart device and metering setup on one to two showers in their homes and to complete a survey on their experience with the ShowerStart device. Table 2 lists the number of homes in the study and the number of ShowerStart devices installed and metered.

Table 2. Pilot Study Sample Summary

Parameter	Quantity	Description
Homes	18	Quantity of participating homes
Fixtures Metered	22	Quantity of ShowerStart devices installed and metered

We collected data over a period of four weeks between September 9 and October 3, 2014. Meters collected data for 22 ShowerStart devices for 17 single-family participants and one multifamily participant living in or around Allentown, Pennsylvania. Four participants who reported frequently using multiple showers each received two devices.

When the field technician returned to the participants' homes to uninstall the metering equipment, he asked the participants to fill out an 11-question satisfaction survey covering the device's functionality, ease of use, appearance, water flow rate, and behavioral changes in shower hot water use. One survey was completed per home.

Metering Approach

A Cadmus field technician installed the ShowerStart device and the metering equipment on showers that participants reported they used most often. The metering equipment consisted of a flow switch/data logger and temperature sensor/data logger as described in Table 3.

Table 3. Metering Equipment

Meter Type	Measurement	Purpose
Flow switch with data logger	Logs an on/off signal whenever shower water flow is present/absent.	Primarily used to determine the behavioral waste flow. Also used to determine structural waste and average shower time.
Temperature sensor with data logger	Measures temperature of the shower water.	Used to determine the average showering temperature.

Two components comprise the total waste water in a showering event:

- **Structural Waste** is the "plug" of cold water that sits in the water pipes prior to the shower event that must be pushed out of the showerhead by incoming hot water before the shower can reach showering temperature. The **structural waste time** is the time required to push the cold water out of the pipes (and replace it with hot water) and is typically referred to as the warmup phase. This time is dependent on the showerhead flow rate and the diameter and length of piping between the water heater and fixture.
- **Behavioral Waste** is the hot water that flows down the drain before the user gets into the shower. The **behavioral waste time** is the length of time the shower runs at showering temperature without the user in the shower.

Together, the ShowerStart device and the metering equipment resembled the setup shown in Figure 1. The metering assembly was installed in line with the ShowerStart device and the showerhead.

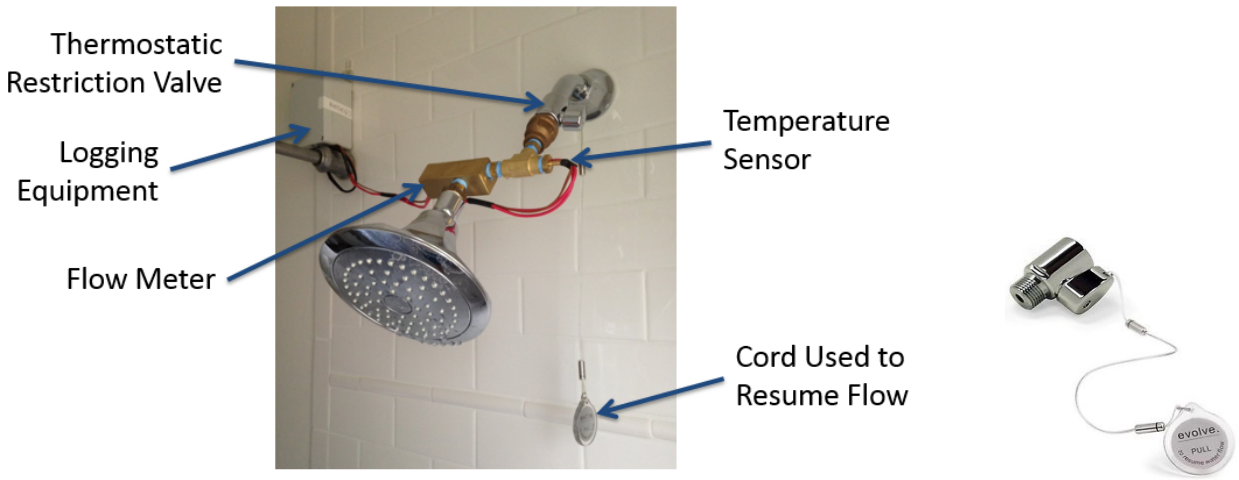


Figure 1. ShowerStart Pilot Study Metering Assembly (left) and the ShowerStart Device (right)

The ShowerStart device reduces the duration of shower behavioral waste. Figure 2 and Figure 3 show two metered shower events from the pilot study, the first without and the second with a ShowerStart device, to demonstrate how the device reduces behavioral waste.

The plot in Figure 2 presents data for an individual shower event in which the ShowerStart device is not engaged during the shower event. In this example, the orange line shows that once the user

turns the shower on, the water temperature slowly rises to a little over 100°F. The structural waste period ends once the temperature has plateaued and the water has warmed up to showering temperature.

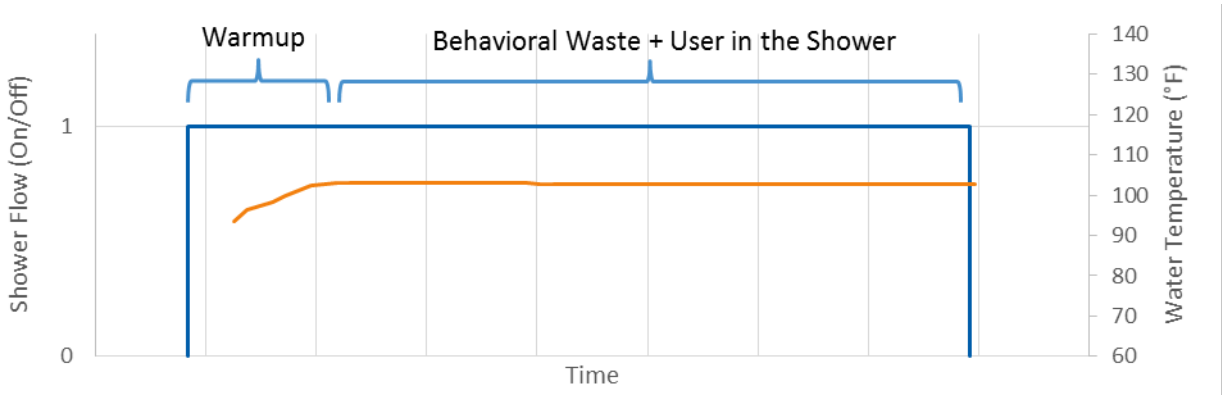


Figure 2. Shower without a ShowerStart Device

The plot in Figure 3 illustrates a shower event that was metered with the ShowerStart device. The orange line shows that once the water temperature reaches approximately 95°F, the ShowerStart device turns the water flow off, ending the warmup phase. The user then pulls the ShowerStart cord to resume the flow of water, ending the phase in which the ShowerStart device is engaged. Toward the end of the shower, the water temperature rises again due to a user temperature adjustment.

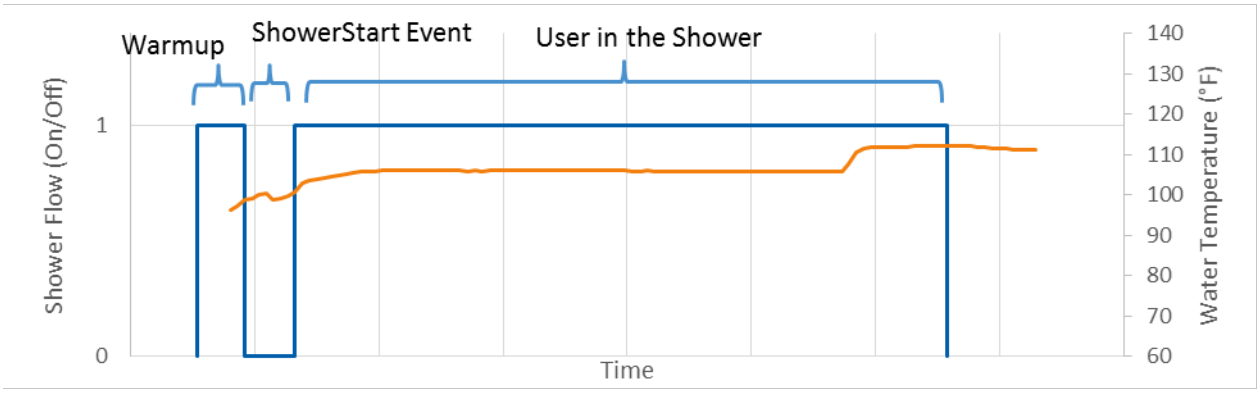


Figure 3. Shower with a ShowerStart Device

For the purposes of this study, shower event time refers to the time captured by all of the phases in Figure 2 and Figure 3—the time for the water to warm up, the time during which the ShowerStart device is engaged (Figure 3 only), and the actual shower time. ShowerStart event time is the duration that the ShowerStart device was engaged, which is a proxy for the behavioral waste duration. Shower water temperature is the temperature of the water saved by the ShowerStart device.

The 2015 PA TRM thermostatic shower restriction valve measure uses the following algorithm to calculate savings:

$$\Delta\, kWh/yr = \frac{ISR \times ELEC \times GPM_{base}}{60\ \frac{sec}{min}} \times UH \times UE \times (T_{out} - T_{in}) \times \frac{(N_{persons} \times N_{showers-day})}{S/_{home}} \times \frac{BehavioralWasteSeconds}{RE} \times 365\ \frac{days}{yr}$$

Where the input value assumptions for a single-family home are:[1]

ISR	=	In-service rate, 100%
ELEC	=	Percentage of home with electric water heat, 43%
GPM_{base}	=	Baseline flowrate, 2.5 GPM
UH	=	8.3 Btu/Gal/°F
UE	=	1/3,412 kWh/Btu
T_{out}	=	Shower water temperature, 101 °F
T_{in}	=	Water main temperature, 55 °F
$N_{persons}$	=	Persons per household, 2.4 people/home
$N_{showers\text{-}day}$	=	Showers per person per day, 0.6 showers/person/day
S/home	=	Showerhead fixtures per home, 1.3 fixtures/home
RE	=	Recovery efficiency of electric water heater, 0.98
BehavioralWasteSeconds	=	ShowerStart event time, 55 seconds

The PA TRM parameters measured in the pilot study were:

BehavioralWasteSeconds	=	ShowerStart event time, seconds
T_{out}	=	Shower water temperature, °F

Results

PA TRM Parameters

The metering work quantified two key parameters required to calculate savings per the 2015 PA TRM algorithm—ShowerStart event time (BehavioralWasteSeconds) and shower water temperature (T_{out}). Table 4 lists the pilot study findings for these parameters along with other metering results. The meters recorded a total of 581 showers with and an average duration of 9.5 minutes.

As shown in Table 4, about one quarter of showers (151 of 581) had no ShowerStart event or had a ShowerStart event with zero duration. Based on how the ShowerStart device functions, the metered data and feedback from the surveys, the four most likely causes for a zero duration are:

- The user pulls the ShowerStart cord to resume water flow so quickly after the ShowerStart device has engaged that the metering equipment cannot register that the water stopped flowing.[2]
- A user takes a shower shortly after a previous shower was taken so that the water in the pipes is already warm and the ShowerStart device is engaged at the beginning of the shower. No warmup period (structural waste) is needed and the user pulls the ShowerStart cord to begin the shower.
- The temperature of the shower water is not hot enough to engage the ShowerStart device (the device activates at approximately 95°F).
- The water pressure in the pipes has temporarily dropped.

[1] See the 2015 PA TRM for a comprehensive list of input parameters and values.

[2] The flow switch meter used in this study records the flow of water as "off" when the flow is below 1 gpm.

Table 4. Metering Results Summary

Parameter	Value	Units	Description
ShowerStart Event Time (BehavioralWasteSeconds)	59	Seconds	Average metered behavioral waste duration
Shower Water Temperature (T_{out})	104	°F	Average temperature of water saved by the ShowerStart device
Number of Shower Events	581	-	Quantity of shower events metered
Number of ShowerStart Events	430	-	Quantity of ShowerStart events metered with a duration greater than zero seconds
Shower Event Time	9.5	Minutes	Average metered shower event duration, which includes warmup and ShowerStart event times, as well as the time the user is in the shower
Structural Waste Time	64	Seconds	Average metered structural waste duration

The ShowerStart event time is the average of ShowerStart event durations with both nonzero and zero values. Including the zero values in this average captures the overall average time that the ShowerStart device is used. The distribution in Figure 4 shows that 455, or about 80%, of ShowerStart events are between zero and one minute in length.

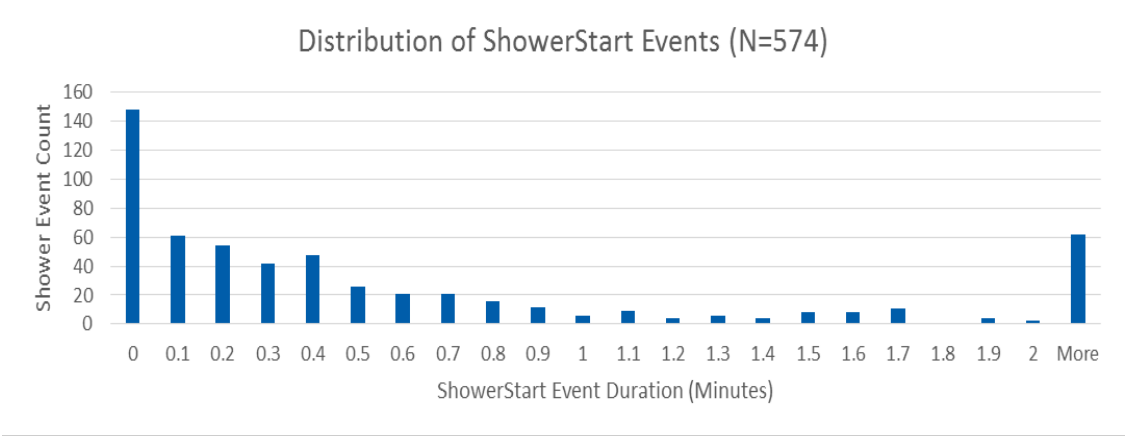


Figure 4. Distribution of ShowerStart Event Times

The shower water temperature is the average temperature of the water for the shower event starting after the ShowerStart event ends. For ShowerStart events with a zero duration, the shower water temperature is the average temperature for the total duration of the shower event.

Table 5 compares the PA TRM parameters measured in the pilot study and those currently reflected in the 2015 PA TRM. The pilot study ShowerStart event time value has a precision of 12.2% compared to the 2015 PA TRM value for which no precision is available.

The 2015 PA TRM shower water temperature value is based on the average water temperature of the entire shower in the PA TRM referenced study, whereas this pilot study metered and determined the average water temperature of the period after the user resumed the water flow by pulling the ShowerStart cord. This value is more accurate than the 2015 PA TRM value because, by excluding the warmup phase of the shower, it better reflects the temperature of the water saved by the ShowerStart device during the behavioral waste period.

Table 5. TRM Key Parameters

Source	Parameter	Value	Units	Precision
2014 Pilot Study	ShowerStart Event Time (*BehavioralWasteSeconds*)	59	Seconds	± 12.2 %
	Shower Water Temperature (T_{out})	104	°F	± 0.3 %
2015 TRM	ShowerStart Event Time[3] (*BehavioralWasteSeconds*)	55	Seconds	N/A
	Shower Water Temperature (T_{out})	101	°F	± 1 %

Energy Savings

Savings are calculated in Table 6 using the algorithm from the 2015 PA TRM and inputs from both the 2015 PA TRM and this 2014 PPL Electric pilot study. The 2014 pilot study savings are slightly higher than those included in the 2015 PA TRM, since both parameters measured in the pilot study (the ShowerStart event time and shower water temperature) increased slightly. The savings in Table 6 include the electric saturation of 43% as prescribed by the 2015 PA TRM.

Table 6. Electric Energy Savings Including Electric Saturation Parameter

Application	Savings [kWh/unit/year]	
	2015 PA TRM	2014 Pilot Study
Single-Family	45.5	52.0
Multifamily	42.6	48.6
Unknown/Default Housing Type	49.3	56.3

In Table 7, the savings do not include the electric saturation and, therefore, these savings are more reflective of a direct install program rather than an upstream program. With a direct install program, the water heating fuel is known through observation and the electric saturation can be set to 100% if the device is installed only in homes with electric water heaters.

Table 7. Electric Energy Savings without Electric Saturation Parameter

Application	Savings [kWh/unit/year]	
	2015 PA TRM	2014 Pilot Study
Single-Family	105.8	120.9
Multifamily	99.0	113.1
Unknown/Default Housing Type	114.6	131.0

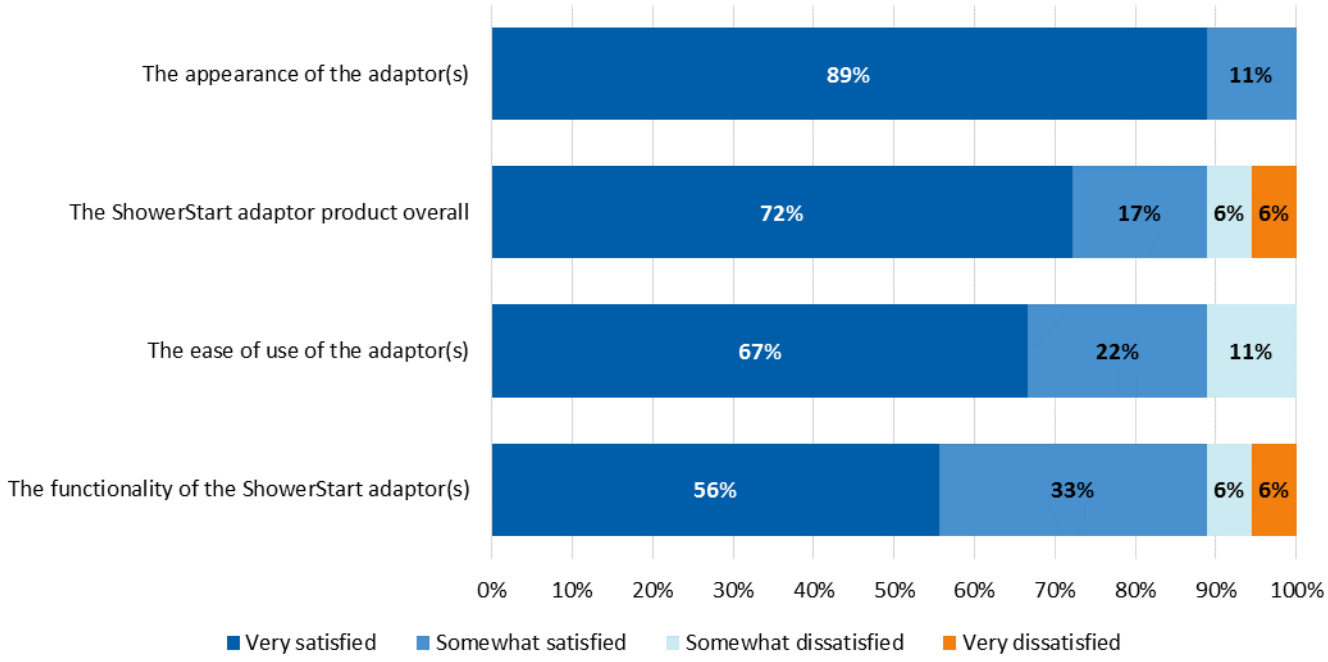
User Satisfaction and Device Usability

As shown in Figure 5, participants were most satisfied with the appearance of the ShowerStart adaptor. Users were not as satisfied when it came to the functionality, ease of use and overall experience. The overall experience the ShowerStart device received 72% "very satisfied" scores, the ease of use category received 67% "very satisfied" and the overall functionality received 56% "very satisfied."

[3] The 2015 TRM ShowerStart Event Time is an estimate based on the 2008 City of San Diego White Paper. Precision not available.

Eleven percent of participants gave "somewhat dissatisfied" or "very dissatisfied" ratings for the device. One participant was "somewhat dissatisfied" because "the water sometimes stops after five minutes of shower use" and the other participant said they were "very dissatisfied" saying, "we are taking our shower in hot water long before it ever shuts off."

Figure 5 shows all of the responses participants reported for satisfaction with the ShowerStart device.



Source: survey Questions A1. "How would you rate your satisfaction with the functionality of the ShowerStart adaptor(s) installed in your home?" B1. "How would you rate your satisfaction with the ease of use of the adaptor(s)?" C1. "How would you rate your satisfaction with the appearance of the adaptor(s)?" and F2. "Considering all of the above, how satisfied are you overall with the ShowerStart adaptor product?" (n=18).

Figure 5. Participant Satisfaction Ratings

Seventeen percent of participants reported experiencing a malfunction with the ShowerStart device. One participant noted the ShowerStart device does not stop the water flow if the water is already hot at the beginning of the shower. Another said that if the water is already hot, the device would not stop the water flow. The third participant reported the water temperature required to shut off the device automatically increased gradually.

Table 8 collects all of the negative feedback (including reported malfunctions) described above and provides possible explanations for the issues described by participants.

Table 8. Negative Participant Feedback

Negative Participant Feedback	Potential Explanation(s)
"The water sometimes stops after five minutes of shower use"	• Low temperature shower causes the device to engage while the user is in the shower • Temporary low water pressure (potentially caused by washing machine use coinciding with shower use)
"We are taking our shower in hot water long before it ever shuts off"	• Low temperature shower causes the device to engage while the user is in the shower (instead of reaching 95°F and shutting off the flow of water before the user enters the shower)
"Water temp on one device seemed to increase b4 shutting off"	• User perception
"How about stops the flow of h20 until the string is pulled?"	• Unclear exactly what this feedback is describing: it's possible that the device is only partially engaging because the water temperature has not exceeded 95°F
"If water is already hot when started it does not stop the flow"	• This user most likely pulled the cord immediately after turning the shower on: the device is already warm from a recent shower and engages and cuts off the flow of water immediately

We asked participants how likely they would be to use the ShowerStart device if the product was offered to them for free. Three-quarters of participants reported they would be "very likely" (78%) to use the device if it were given to them for free, and 11% said they were "somewhat likely." The two participants who reported they would be "somewhat unlikely" or "very unlikely" to use the device if provided to them for free also said they experienced a malfunction with the device.

ShowerStart Behavior Change

We asked participants if the ShowerStart device changed the amount of time spent waiting between starting the shower water and getting in the shower. Nearly half (44%) of the participants reported no change, 28% reported waiting more time, and another 28% reported waiting less time.

Only two of 18 participants (11%) reported changing the water temperature they normally set when they first start the shower because of the ShowerStart device.

Based on these responses to the survey, our analysis assumed that the PA TRM values measured during the pilot study -- behavioral waste duration and shower water temperature -- equal those from before the study.

Additional Findings

We found that the ShowerStart device is not compatible with all shower fixtures. In one instance, the metering assembly was not installed on a fixture because the water pressure was too low for the ShowerStart device to function properly.[4] There were also several shower fixtures with plastic aerators in the existing fixture, which prevented the ShowerStart device from screwing onto the shower fixture.

Conclusions

Through the use of water metering and a participant satisfaction survey, PPL Electric and Cadmus updated two parameters used in the 2015 PA TRM to calculate energy savings for the thermostatic shower valve measure. Although the pilot study did not dramatically change the values of

[4] ShowerStart device should not be installed in homes where the water pressure is below 30 psi, according to "Contractor Information Sheet," p. 2. Available online: http://showerstart.com/contractors-installers/.

the two savings parameters, the values did increase slightly and the precision around these parameters improved significantly.

The study revealed that about one-quarter of those who shower do not waste water by allowing hot shower water to go down the drain: for these cases the device did not produce energy savings. For the three-quarters of participants who did allow hot shower water to go down the drain, the ShowerStart did capture savings: an average of 121 kWh per installation for a single family home with an electric hot water heater. These updated input values are included in the new version of the PA TRM.

Results from the participant survey addressed study objectives related to product functionality, usability, and user satisfaction. The survey found that 28% of users were less than very satisfied with the product, 33% were less than very satisfied with its ease-of-use and 44% were less than very satisfied with the functionality of the product. These survey results point to some dissatisfaction and confusion with how to use the device. These issues may be addressed through improved user education that targets the specific feedback identified in Table 8.

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