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NAVIGANT

To: **Interested Parties in Illinois**
From: **Charles Ampong, Navigant[1]**
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Subject: **Illinois TRM Evaluation Research – Multi-Family Thermostatic Shower Restriction Valve Measure & Pipe Insulation Measures**

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Executive Summary

Navigant conducted evaluation research that may assist the Illinois TRM Technical Advisory Committee annual updating process and to validate engineering assumptions for parameter values not specified in the State of Illinois Technical Reference Manual (IL TRM).[2] This memorandum presents evaluation research for two measure categories: 1) a thermostatically initiated shower restriction valve on a showerhead for residential applications in Illinois and 2) hot water and steam pipe insulation measures in building common areas. Information about the pipe insulation measures was supplied by the program's implementation contractor.[3]

Thermostatic Shower Restriction Valve Measure for Residential Applications in Illinois

The purpose of this section is to present research on potential energy and water savings from installing a thermostatically initiated shower restriction valve on a showerhead. Navigant's research focused on a unique and patented shower restriction valve technology available in the retail market called ShowerStart™ [1]. This device has been tested to provide energy and water savings in other jurisdictions, and thus serves as a basis for preliminary research on the device's operation and potential savings for Illinois utility energy efficiency programs.

The Table 1 below presents a summary of potential savings from installing ShowerStart on a previously installed 1.5 gallons per minute (GPM) water efficient showerhead. Presuming that the installation of a 1.5 GPM water efficient showerhead provides a baseline case for the ShowerStart device, Navigant's estimates in the table below do not include water/energy savings from installing a 1.5 GPM water efficient showerhead at the water source. Navigant's research indicates that installing ShowerStart devices can potentially save an additional 3.2 therms/yr or 75 kWh/yr in single family homes and 4.2 therms/yr or 84 kWh/yr in multifamily homes. These additional savings can result in a 2.3 year simple payback for electric water heat and a 4.6 year simple payback for gas water heat in multifamily homes.

Table 1. Potential Savings from Installing ShowerStart on 1.5 GPM Showerhead

ShowerStart Savings Calculations	Single Family	Multi-Family
Water savings (gallons/yr/ShowerStart)	588	664
Electric Energy Savings (kWh/yr/ShowerStart)	75	84
Peak Demand savings (KW/yr/ShowerStart)	0.005	0.007
Gas energy savings (therms/yr/ShowerStart)	3.2	4.2
Simple Payback Period	2.3 years electric water heater 4.6 years gas water heater	

Source: Navigant Research

[2] State of Illinois Technical Reference Manual. Final as of September 14, 2012, effective June 1, 2012. http://ilsagfiles.org/SAG_files/Technical Reference Manual/Illinois Statewide_TRM_Version_1.0.pdf
[3] Integrys_Master_Measure_Document 010213.xlsx (see spreadsheet Tab 31: MF Common Area Pipe Wrap).

ShowerStart™ Technology Description

As illustrated in Figure 1 below, the ShowerStart device is described by the manufacturer as a "compact, thermostatic valve that automatically pauses a shower's water flow once it reaches bathing temperature" [2]. The thermostatic valve can be installed in-between the shower arm and existing showerhead, and it is expected to detect when near-bathing-temperature water (95F/35C) arrives at the shower head.

Figure 1. Evolve Showerhead ShowerStart Device

(Source: www.showerstart.com)

Once installed and operational, the device is expected to automatically reduce the showerhead's flow to a trickle, and as a result prevent hot water from unintentionally running down the drain while the user is away. When ready to begin showering, the user can pull the thermostatic valve's fob to resume normal showerhead flow [3].

Water Savings Potential and Calculation

The potential to reduce hot water waste and produce energy savings from a shower restriction device depends primarily on accurate estimation of the time hot water arrives at the shower and the time an individual enters the shower. Limited information exists on how much hot water is avoided or wasted before a user gets into the shower after installing the device, and accordingly how long the wasted hot water is left to run. From a few available surveys and research studies on the functions of shower restriction devices, we can estimate the total time that passes between turning on the shower and entering the shower (pre-retrofit warm up wait time out of the shower spent on bathroom activities), and how much time it takes before the hot water arrives at the shower (cold water warm-up time). The difference between these two estimates represents the hot water wait time that could be prevented due to installation of the shower restriction device.

Table 2 below provides average estimates of the hot water wait time deduced from residential shower behavior studies. ShowerStart LLC estimates that total warm-up wait activities will take about 106 seconds to complete, while it takes 46 seconds for warm water to arrive at the shower, resulting in 60 seconds of hot water waste time that could have been prevented with the use of the ShowerStart device. Based on the results from a pilot study conducted by California's City of San Diego Water Department, an average of 52 seconds of hot water waste time can be deduced [4]. The Pacific Gas and Electric Company (PG&E) relied on what they considered to be a conservative value of 34 seconds hot water waste time to calculate the potential savings from shower restriction devices in their service territory [5].

Table 2. Estimates of Avoided Shower Hot Water Waste Time

Study Type	Hot Water Waste Time (sec)	Sources (See reference section for study reports)
Survey	60	ShowerStart LLC
Survey	52	City of San Diego Water Department
Research Studies	34	Pacific Gas and Electric Company (PG&E)

Sources: see reference section

ShowerStart LLC estimated each ShowerStart installed in a typical single family home with 3 persons could yield up to 2700 gallons of water savings annually (assuming a 2.5 GPM showerhead). The City of San Diego estimated 2400 gallons annual savings for a similar household size. The PG&E conducted a more in depth analysis and came up with estimates for low flow 1.6 GPM showerheads, and estimated 296 gallons annual water savings for single family homes, and 435 gallons for multifamily homes.

It is important to note that it is possible the ShowerStart device may not realize any savings. A typical example would be a situation where an individual has a habit of opening the bath faucet during the warm up time, such that the showerhead is used immediately when the water temperature is deemed warm enough to start shower.

Engineering Estimate of Water Savings from Using ShowerStart

Using the Illinois TRM section 5.4.5, Navigant applied savings assumptions and algorithm for the showerhead replacement measure to estimate potential water and energy savings from installing a ShowerStart device. Savings estimates have been provided for both 2.67 GPM base flow showerheads and 1.5 GPM low flow efficient showerheads in single family and multifamily homes [6].

Calculations:

Annual Water Savings from ShowerStart = Avoided annual water use from showerhead

Water savings for 2.67 GPM showerhead installed with ShowerStart = [((GPM_base_SS * L_showerstart) * Household * SPCD * 365.25 / SPH) * ISR_ss]

Water savings for 1.5 GPM low flow showerhead installed with ShowerStart = [((GPM_low_SS * L_showerstart) * Household * SPCD * 365.25 / SPH) * ISR_ss]

Where:
GPM_base_SS= Flow rate of the base case showerhead with ShowerStart (2.67 GPM)
GPM_low_SS= As-used flow rate of the low-flow showerhead with ShowerStart (1.5 GPM)
Household= Average number of people per household (2.56 for single family, and 2.1 for multifamily)
SPCD= Showers Per Capita Per Day (0.75)
365.25= Days per year, on average.
SPH= Showerheads Per Household (1.79 for single family, and 1.3 for multifamily)
ISR_ss= In service rate of ShowerStart device (assumed 100%)
L_showerstart= Hot water waste time avoided due to ShowerStart (1 minute) per shower

For the purpose of this engineering estimate, we assumed on average of 60 seconds of hot water time is avoided for installing thermostatic shower restriction devices. This value is subject to review upon further detailed studies conducted within Illinois residential facilities to understand household shower behavior and the amount of water and energy that can be saved by installing shower restriction devices. The resulting water savings estimate is applied for both electric water heaters and natural gas water heaters are shown in Table 3.

As shown in Table 3 below, a ShowerStart device installed on a 2.67 GPM base flow showerhead could save 1,046 gallons annually in a typical single family home and 1,182 gallons annually in a multifamily home in Illinois. A ShowerStart device installed on a 1.5 GPM low flow showerhead could save 588 gallons annually in a typical single family home and 664 gallons annually in a multifamily home in Illinois. These savings represent an additional 16% and 17% increase respectively, above the savings achieved by retrofitting a 2.67 GPM showerhead to a 1.5 GPM showerhead, based on the TRM estimated annual savings for installing low flow showerhead that is 3,684 gallons for single family, and 3,948 gallons for a multifamily home.

Table 3. Potential Water Savings for ShowerStart Device in Illinois

Water Savings Calculations	Single Family	Multi-Family
Water savings from installing ShowerStart on 2.67 GPM base showerhead (gallons/yr/ShowerStart)	1,046	1,182
Water savings from installing ShowerStart on 1.5 GPM low flow showerhead (gallons/yr/ShowerStart)	588	664
Percent increase in water savings on a 1.5 GPM low flow showerhead retrofit	16%	17%

Source: Navigant research

Energy Savings Potential and Calculation

Navigant estimated energy savings potential for both 2.67 GPM base flow showerheads and 1.5 GPM low flow showerheads installed with a ShowerStart device in a single family and multifamily homes.

Engineering Estimate of Electric Energy Savings from ShowerStart

As shown in Table 4 below, a ShowerStart device installed on a 2.67 GPM base flow showerhead could save an additional 133 kWh annually in a typical single family home and 150 kWh annually in a multifamily home in Illinois. A ShowerStart device installed on a 1.5 GPM low flow showerhead could save an additional 75 kWh annually in a typical single family home and 84 kWh annually in a multifamily home in Illinois. These savings represent additional 16% and 16% increase respectively, given that the TRM estimated annual energy savings for installing a 1.5 GPM low flow showerhead is 468 kWh for single family, and 528 kWh for a multifamily home.

Calculations:

Annual Electric Energy Savings from ShowerStart = Avoided annual electrical energy use from showerhead

Avoided electrical energy savings for 1.5 GPM low flow showerhead installed with ShowerStart = [%ElectricDHW * (GPM_low_SS * L_showerstart) * Household * SPCD * 365.25 / SPH) * EPG_electric]*ISR_ss

Where:
%ElectricDHW = proportion of water heating supplied by electric resistance heating (100%)
EPG_electric = Energy per gallon of hot water supplied by electric (0.127 kWh/gallon)
Other variables as defined above.

Table 4. Potential Electric Energy Savings for ShowerStart Device in Illinois

Electric Energy Savings Calculations	Single Family	Multi-Family
Electric Water Heater savings from installing ShowerStart on 2.67 GPM base showerhead (kWh/yr/ShowerStart))	133	150
Electric Water Heater savings from installing ShowerStart on 1.5 GPM low flow showerhead (kWh/yr/ShowerStart)	75	84
Percent increase in electrical energy savings on a 1.5 GPM low flow showerhead retrofit	16%	16%

Source: Navigant research

Engineering Estimate of Electrical Demand Savings

As shown in Table 5 below, annual peak demand savings for ShowerStart device installed on a 2.67 GPM base flow showerhead could be 0.009 KW in a typical single family home and 0.012 KW in a multifamily home in Illinois. Annual peak demand savings for ShowerStart device installed on a 1.5 GPM low flow showerhead could be 0.005 KW in a typical single family home and 0.007 KW in a multifamily home in Illinois.

Calculations:

Annual Peak Demand Savings from ShowerStart = Avoided annual peak demand from showerhead

$\Delta kW = \Delta kWh/Hours * CF$

Where:
ΔkWh = calculated kWh value in Table-3 above
Hours = Annual electric DHW recovery hours for showerhead use (431 for SF DI; 354 for MF DI)
CF = Coincidence Factor for electric load reduction (=0.0278)

Table 5. Potential Demand Savings for ShowerStart Device in Illinois

Electric Demand Savings Calculations	Single Family	Multi-Family
Electric Water Heater savings from installing Peak Demand savings from installing ShowerStart on 2.67GPM base showerhead (KW/yr/ShowerStart)	0.009	0.012
Peak Demand savings from installing ShowerStart on 1.5GPM low flow showerhead (KW/yr/ShowerStart)	0.005	0.007

Source: Navigant research

Engineering Estimate of Natural Gas Energy Savings

As shown in Table 6 below, a ShowerStart device installed on a 2.67 GPM base flow showerhead could save an additional 5.6 therms annually in a typical single family home and 7.4 therms annually in a multifamily home in Illinois. A ShowerStart device installed on a 1.5 GPM low flow showerhead could save an additional 3.2 therms annually in a typical single family home and 4.2 therms annually in a multifamily home in Illinois. These savings represent additional 16% and 17% increase respectively, given that the TRM estimated annual energy savings for installing a 1.5 GPM low flow showerhead is 19.9 therms for single family, and 24.9 therms for a multifamily home.

Calculations:

Natural gas energy savings from ShowerStart = Avoided annual therms energy use from showerhead

Avoided therms energy savings for 1.5gpm low flow showerhead installed with ShowerStart =%FossilDHW * ((GPM_low_SS * L_showerstart) * Household * SPCD * 365.25 / SPH) * EPG_gas * IRS_ss

Where:
%FossilDHW = *proportion of water heating supplied by natural gas heating (100%)*
EPG_gas = Energy per gallon of hot water supplied by gas (0.0054 therm/gal SF, 0.0063 Therm/gal MF)
Other variables as defined above.

Table 6. Potential Gas Therms Savings for ShowerStart Device in Illinois

Gas Therm Savings Calculations	Single Family	Multi-Family
Natural gas energy savings from installing ShowerStart on 2.67 GPM base showerhead (therms/yr/ShowerStart)	5.6	7.4
Natural gas energy savings from installing ShowerStart on 1.5 GPM low flow showerhead (therms/yr/ShowerStart	3.2	4.2
Percent increase in natural gas therms savings on a 1.5 GPM low flow showerhead retrofit	16%	17%

Source: Navigant research

Cost Savings

As shown in Table 7 below, the national average cost of water is approximately $0.002/gallon, according to the United States Environmental Protection Agency [7]. The average cost to heat water

from a standard gas water heater is estimated as $0.008/gallon, and $0.017 for an electric water heater [8]. Assuming that users typically turn their mixing valve all the way to the hot position in the warm-up process, and the average hot water cost savings for an electric water heater is $0.02/gallon, gas water heating is $0.01 per gallon, and the unit cost of ShowerStart is $29.95, we can estimate the net savings in utility bills for each ShowerStart installed. Table-7 and Table-8 below illustrate potential cost savings for installing thermostatic shower restriction valves in multifamily and single family residences.

Table 7. Potential Cost Savings from Installed ShowerStart device (Multifamily)

Cost Savings for Multifamily	ShowerStart with 2.67 GPM base showerhead	ShowerStart with 1.5 GPM low flow showerhead
Water Savings (gallons/yr/ShowerStart)	1,182 gallons	664 gallons
Utility Bill Savings ($/yr/ShowerStart)	$23.64 Electric WH $11.82 Gas WH	$13.28 Electric WH $6.64 Gas WH
Net Savings (bill savings - unit cost)	($6.31) Electric WH ($18.13) Gas WH	($16.67) Electric WH ($23.31) Gas WH
Payback Period	1.3 years (Elec.) 2.6 years (Gas)	2.3 years (Elec.) 4.6 years (Gas)

Source: Navigant research

Table 8. Potential Cost Savings from Installed ShowerStart device (Multifamily)

Cost Savings for Multifamily	ShowerStart with 2.67 GPM base showerhead	ShowerStart with 1.5 GPM low flow showerhead
Water Savings (gallons/yr/ShowerStart)	1,046 gallons	588 gallons
Utility Bill Savings ($/yr/ShowerStart)	$20.92 Electric WH $10.46 Gas WH	$11.76 Electric WH $5.88 Gas WH
Net Savings (bill savings - unit cost)	($9.03) Electric WH ($19.49) Gas WH	($18.19) Electric WH ($24.07) Gas WH
Payback Period	1.4 years (Elec.) 2.9 years (Gas)	2.5 years (Elec.) 5.1 years (Gas)

Source: Navigant research

Conclusion

As discussed above, additional 16 percent of water and energy savings may be realized from installing a ShowerStart device on a 1.5 GPM efficient showerhead. Additional cost savings ranging

from an estimated $6.00 to $24.00 may be accrued from installing a ShowerStart device in single family and multifamily homes.

Suggested Additional Research

1. Further studies are required to understand users' shower behavior, and to enable accurate determination of the pre-shower hot water wait time in the State of Illinois.
2. Further research is necessary to investigate the showerhead flow rate during trickling due to operation of the shower restriction valve.
3. Further research is necessary to investigate how much hot water is wasted before a user enters into the shower when a shower restriction valve is installed, and how long this wasted hot water is left to run.
4. Further studies could focus on investigating whether shower restriction valves interfere with the flow rate and consequently affect the energy savings from a low flow showerhead, causing savings estimates to be revised for one or both devices.
5. Research on shower behaviors should include the impact of situations where users normally open the faucet tap during the warm up time. Such discussion was lacking in the reference materials, but the possibility could render the thermostatic restriction valve virtually non-operational, and thus produce zero savings. Alternatively, if the pre-retrofit scenario involved hot water waste through the faucet and post-retrofit behavior changed to using the showerhead for warm up time, savings could be greater.

References

1. ShowerStart LLC (www.showerstart.com)
2. "Simply & Cost Effectively Reducing Shower Based Warm-Up Waste: Increasing Convenience & Conservation by Attaching ShowerStart to Existing Showerheads" (ShowerStart LLC, 2008).
3. "Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart" (ShowerStart LLC, May 2013).
4. "Water Conservation Program: ShowerStart Pilot Project White Paper", (City of San Diego, CA, August 2008).
5. Pacific Gas and Electric Company (Work Paper PGECODHW113, Low Flow Showerhead and Thermostatic Shower Restriction Valve, Revision # 4, August 2012).
6. Illinois Statewide Technical Reference Manual for Energy Efficiency (June 2013, Version 2.0, section 5.4.5).
7. www.epa.gov/safewater, "Water on Tap, What You Need to Know", 2009.

8. Smart Energy Design Assistance Center, University of Illinois, Urbana, Champaign; Newsletter Vol. 6, No. 6, June 2010, (www.sedac.org).

Hot Water & Steam Pipe Insulation Measures

Navigant conducted research to validate engineering assumptions for parameter values not specified in the IL TRM, including hot water and steam pipe insulation measures in building common areas, which were supplied by the program's implementation contractor. [4] Navigant used the algorithm presented in Figure 7-1 below to calculate verified gross savings for steam pipe insulation measures.

Figure 7-2. Verified Gross Savings Algorithm – Steam Pipe Insulation

$$Verified\ Gross\ Annual\ Therm\ Savings\ per\ Foot = ((Qbase - Qeff) * HOURS) / (100{,}000 * \eta Boiler)) * CF$$

Where:

- Q_{base} = Heat Loss from Bare Pipe (Btu/hr/ft). See Table 7-17-1 below.
- Q_{eff} = Heat Loss from Insulated Pipe (Btu/hr/ft). See Table 7-17-1 below.
- Hours = Annual operating hours (actual or defaults by piping use and building type)
- 100,000 = conversion factor (1 Therm = 100,000 Btu)
- ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe (=80.7% for steam boilers)
- CF = Heat loss correction factor of 0.67

Navigant reviewed steam pipe insulation measure savings inputs from the program implementation contractor. The implementation contractor developed heat loss estimates (Qbase and Qeff) using the 3E Plus v4.0 software program[5]. The energy savings analysis is based on engineering assumptions using an average of 1.5-inch insulation around bare pipe. Details of the input parameters to 3E plus used to develop savings estimates are shown in Table 7-17-1 below.

[4] Integrys_Master_Measure_Document 010213.xlsx (see spreadsheet Tab 31: MF Common Area Pipe Wrap).
[5] 3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association).

Table 7-9. Steam Pipe Insulation Savings Parameters

Parameter	Value	Data Source
R value of pipe insulation	5.0 (1.5 inches of insulation with K of 0.27)	IECC 2009
DI-R value of pipe insulation	3.0 (1.5 inches of insulation with K of 0.28)	IECC 2009
Linear feet of pipe	1	Standard value
Pipe temperature	225 F	Engineering assumption
Ambient temperature	75F	Engineering assumption
Combustion Efficiency	80.7%	Engineering assumption
Nominal Pipe Size	Varies	Engineering assumption
BTU loss/hr, uninsulated	Varies	Calculation using 3E Plus
BTU loss/hr, insulated	Varies	Using 3E Plus
BTU loss/hr, savings	Varies	Using 3E Plus
Hours of Operation/year	4,963	TMY3 Weather Data from O'Hare Int'l Airport
Heat Loss Correction Factor	0.67	Engineering Assumption
BTU/therm Conversion Factor	100,000	Standard value
Therms/year saved	Varies	Calculation
DI-Therms/year saved	Varies	Calculation
Nominal Therms/year saved	Varies (Average of all pipe sizes)	Calculation
DI-Nominal Therms/year saved	Varies (Average of all pipe sizes)	Calculation

Source: *Navigant analysis of Integrys_Master_Measure_Document 010213.xlsx*

If you have any questions or wish to discuss the findings in this memo then please contact Charles Ampong at 608-497-2336.