Do Improved Hot Water Systems Result In Efficient Consumer Behaviors

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- Create effective efficiency that improves user comfort and convenience.

Hot Water Service

What Are We Aiming For?

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The 2 Most Desired Services

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Never Run Out ="Continuousness"

- Need a large enough tank or
- A large enough burner or element
- Or, a modest amount of both

Hot Water Performance Metrics For Service

- **Temperature**

  ≥ 110F, hot enough to shower in

- **Volume-until-hot**

  Goal is no more than 1 cup after opening tap

  Settle for 2-3 cups, maybe 4

- **Time-to-tap**

  Structural waste should be consistent and small

  < 1 second, possible, but probably energy expensive

  < 5 seconds, very buildable

  < 10 seconds, "Acceptable" according to ASPE

Hot Water System Elements

Domestic Hot Water System Components

Creation

water heater

Domestic Hot Water System Components

Creation

Structure/Delivery

water heater

plumbing

Domestic Hot Water System Components

Creation | Structure/Delivery | Behavior

water heater

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human interaction

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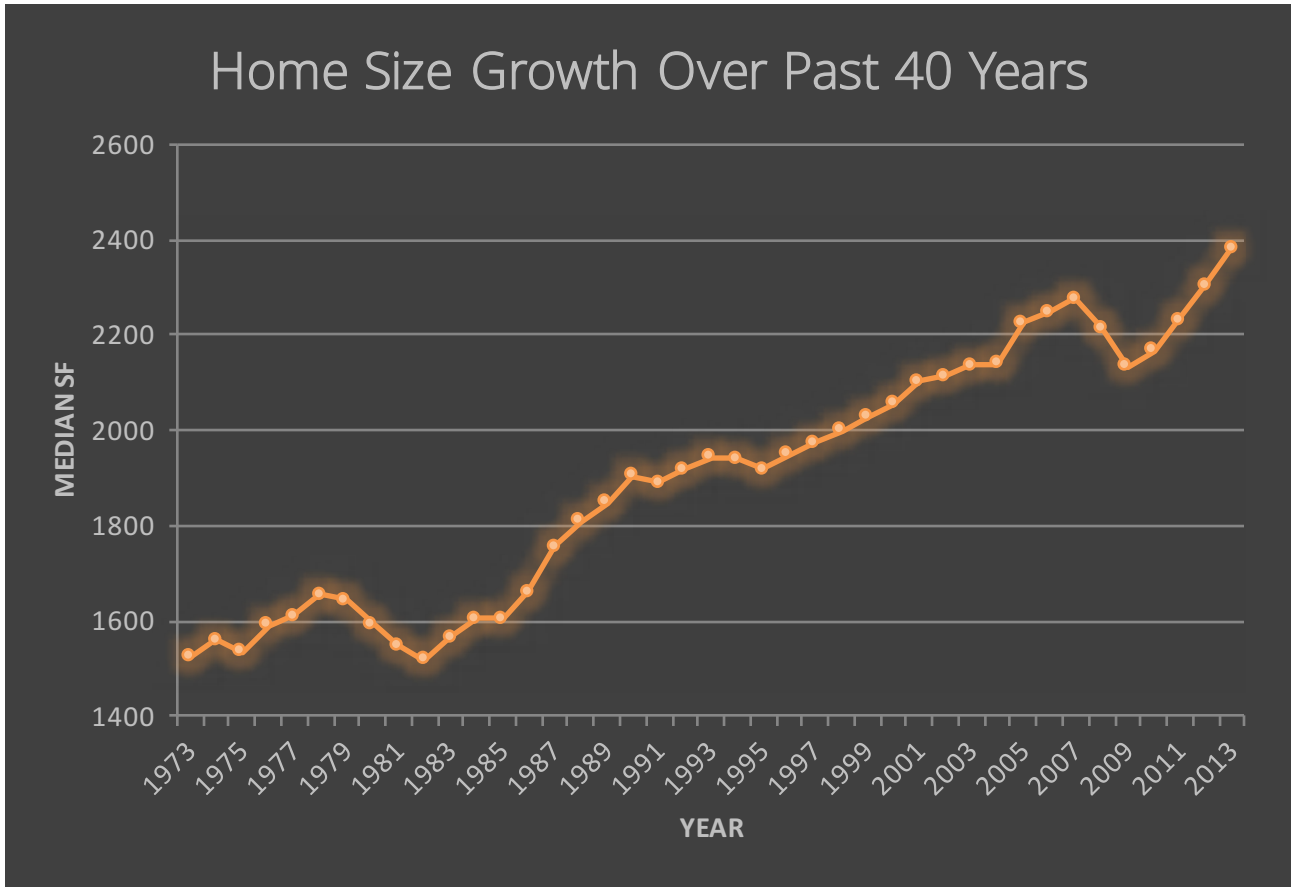
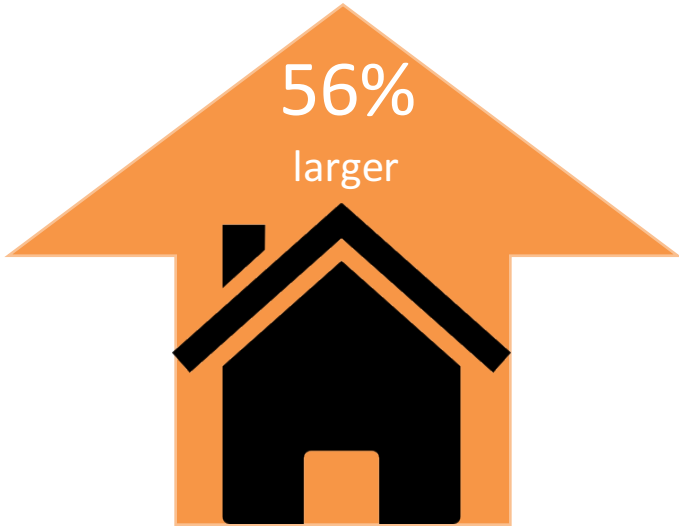
If We Don't Address These Areas
Homes Remain Inefficient &
Customers Interactions Are Negative

Hot Water
Plumbing Structure

We Have A Growing Problem

The median new home size in the US has grown from 1,500 SF in 1973 to nearly 2,400 SF in 2013 – 56%





SOURCE: US Census Bureau

Hot Water Use Has Large And Growing Impact On A Home's Water & Efficiency

Hot water heating is now the second largest use of energy in the home at about 20% of all energy use.

Heating Water 1st or 2nd Largest Energy Use In Home

Heating water is first in some climates and very efficient dwellings - second largest use of energy in a home after heating and cooling.

SOURCE: Energy Information Administration, Office of Energy Consumption and Efficiency Statistics, 2009 Residential Energy Consumption Survey

Hot Water Distribution Dynamics

Once heated, the hot water must be delivered to the intended point of use in the home.

Factors influencing distribution efficiency:

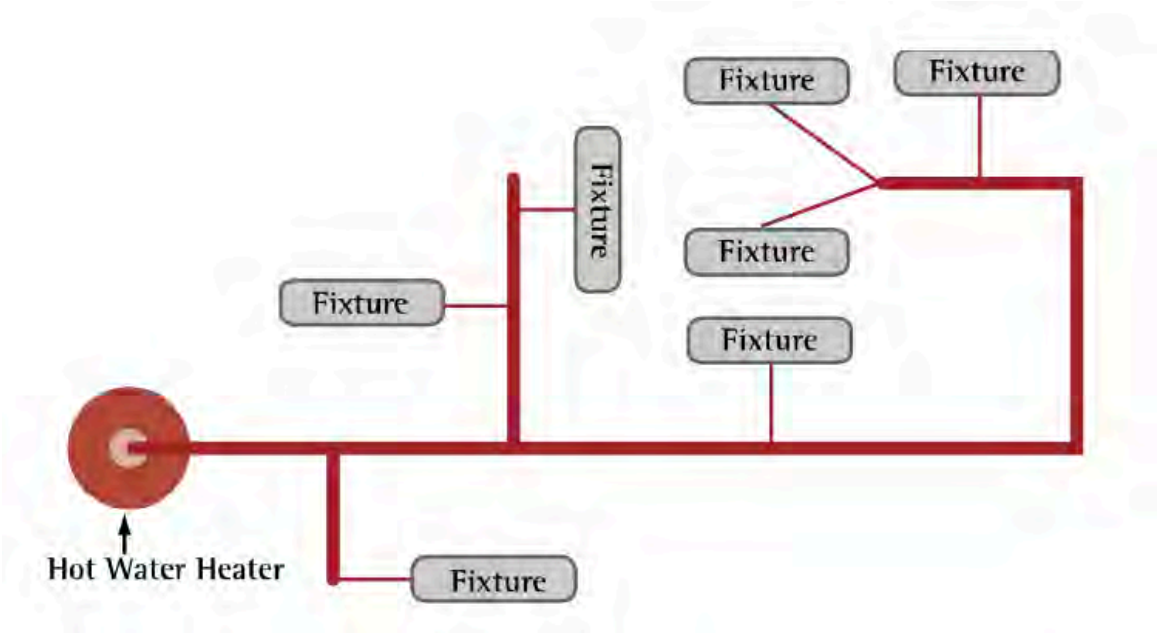
- Length of piping between heater and fixtures
- Pipe diameter and materials
- Pipe insulation

Greater Distances Mean Longer Waits

Water volumes sitting in the hot water line must be purged before hot water arrives at the point of use.

Most Popular Plumbing Configuration – Trunk & Branch

Characterized by one long. Large diameter main line (trunk) that runs from the water heater to the farthest fixture in the house. Smaller diameter branches then supply water to fixtures.



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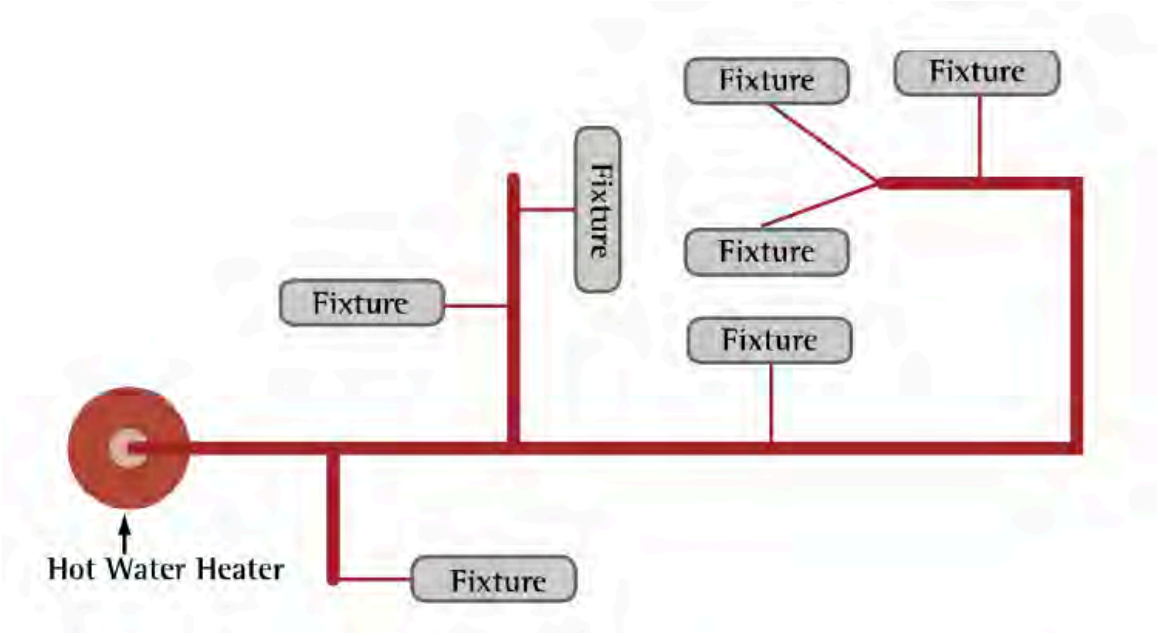

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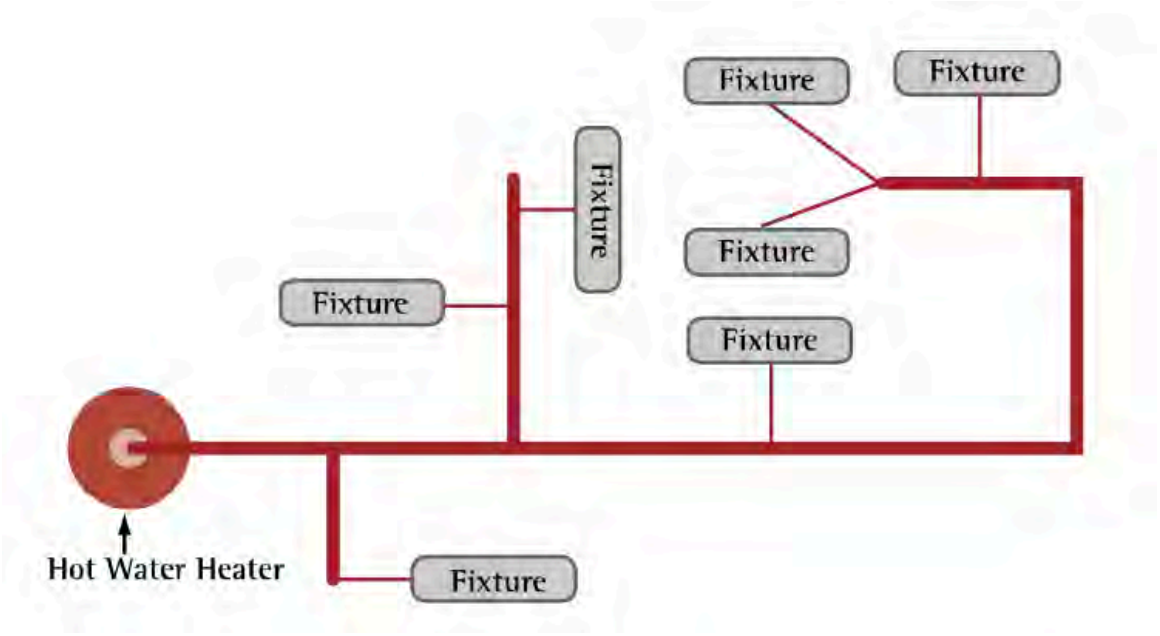

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3,650 Gal. Wasted

average loss home/yr. waiting for hot water to arrive at the point of use

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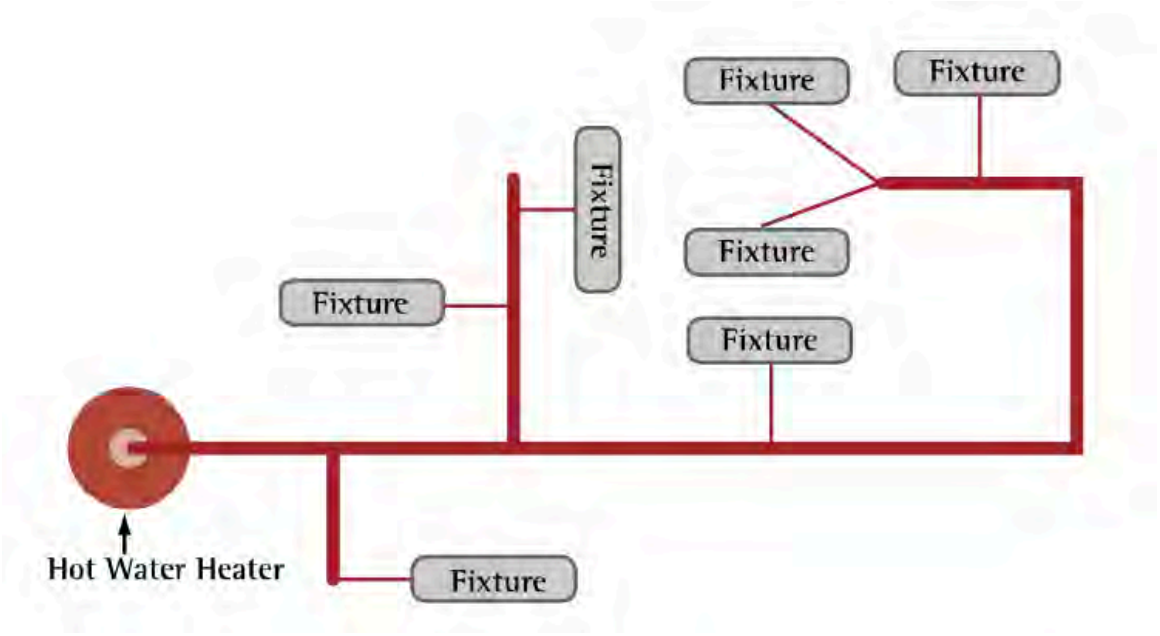

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Lower Flow Rates Mean Even Longer Waits

All things being equal, we've increased wait times 2x-3x over the past 25 years. But all things aren't equal!

Flow Rate	Volume To Purge	Seconds Waiting
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2X – 3X Longer Wait For Hot Water To Arrive

But Lower Flow Rates Have Much Greater Impact Than We Realize – They Actually Increase The Volume To Purge

At lower flow rates, 50% or more water must clear the pipe than is actually sitting in the pipe before hot water becomes available at the point of use.

PLUG FLOW (+ 5 gpm)

distance < 1 foot

0% - 10%

more than volume of pipe

SOURCE: Koeller, J (2007) Residential Hot Water Distribution Potential Best Management Practices.pdf

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EPA
EPAct of 1992
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HOT SLIDES UP OVER COLD (<1 gpm) distance + 20 feet

50% - 100%
more than volume of pipe

WaterSense Meets EPA Criteria

SOURCE: Koeller, J (2007) Residential Hot Water Distribution Potential Best Management Practices.pdf

How Long Should We Wait For Hot Water?

Volume in the Pipe (ounces)	Minimum Time-to-Tap (seconds) at Selected Flow Rates					
	0.25 gpm	0.5 gpm	1 gpm	1.5 gpm	2 gpm	2.5 gpm
2	4	1.9	0.9	0.6	0.5	0.4
4	8	4	1.9	1.3	0.9	0.8
8	15	8	4	2.5	1.9	1.5
16	30	15	8	5	4	3
24	45	23	11	8	6	5
32	60	30	15	10	8	6
64	120	60	30	20	15	12
128	240	120	60	40	30	24

ASPE Time-to-Tap Performance Criteria

	Acceptable Performance	≤ 10 seconds
	Marginal Performance	> 10 ≤ 30 seconds
	Unacceptable Performance	> 30 seconds

Source: Domestic Water Heating Design Manual – 2nd Edition, ASPE, 2003, page 234

The Structural Answer

SHORT, *Smooth*, Right-Sized pipe

We've Been Talking About
Improved Plumbing Design Today

People Won't Waste Hot Water
If It Arrives Quickly
– Right?

December 2013 LBNL Field Study – DHW Use

Lawrence Berkeley National Lab conducted a field study of domestic hot water usage in N. California homes. Evolve Technologies identified the following data points regarding shower usage in homes with usable data for the period Dec 1-31, 2013.

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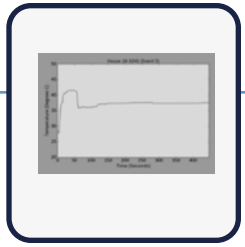

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- 528 total events
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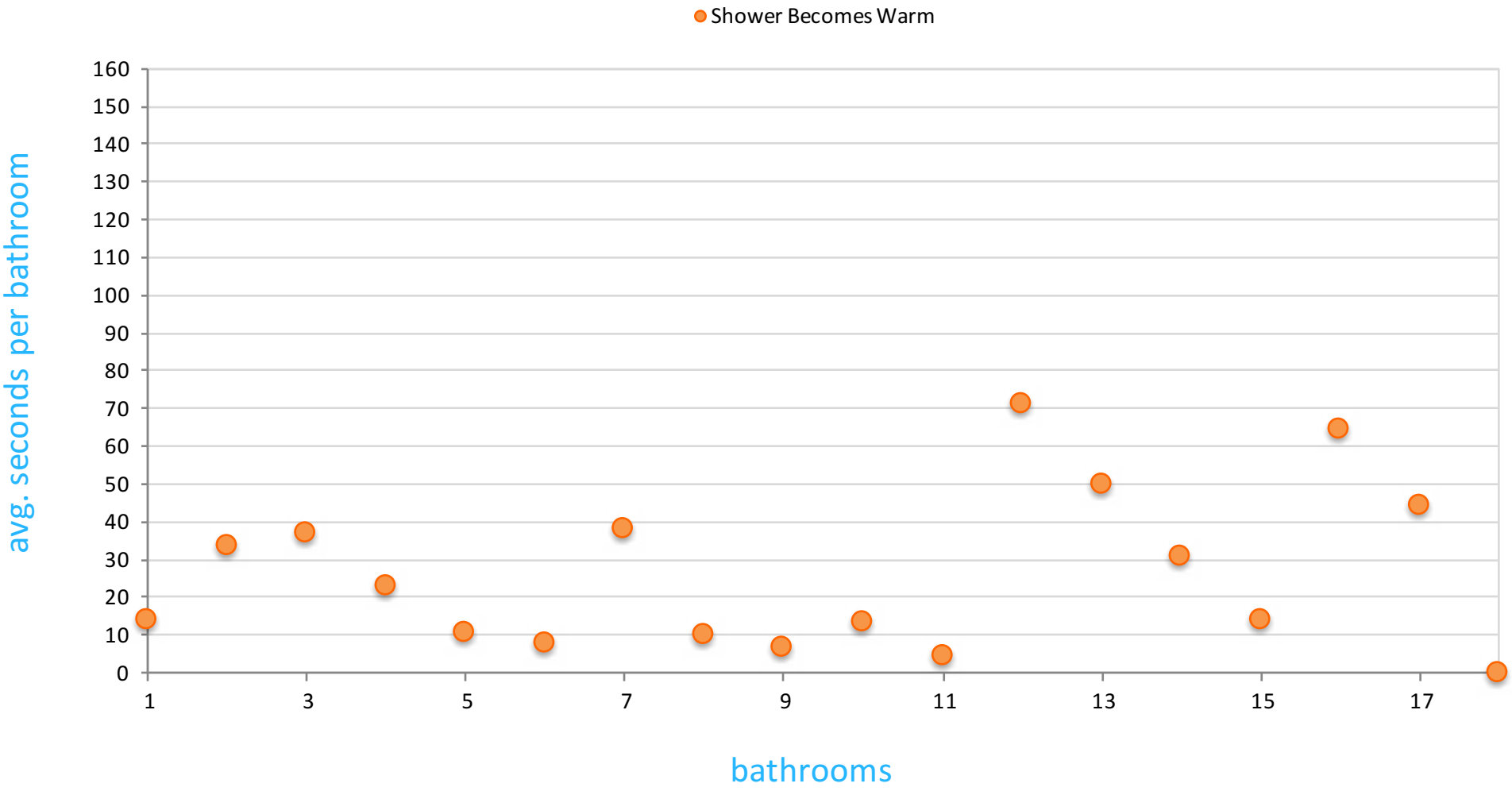
SOURCE: 2014 Disaggregating Residential Shower Warm-Up Waste – An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Lab

Behavior Is Persistent – 10 Sec Waits Are Too Long

50% of bathrooms average about a 10 second wait for hot water, but exhibited above average Behavioral Waste.



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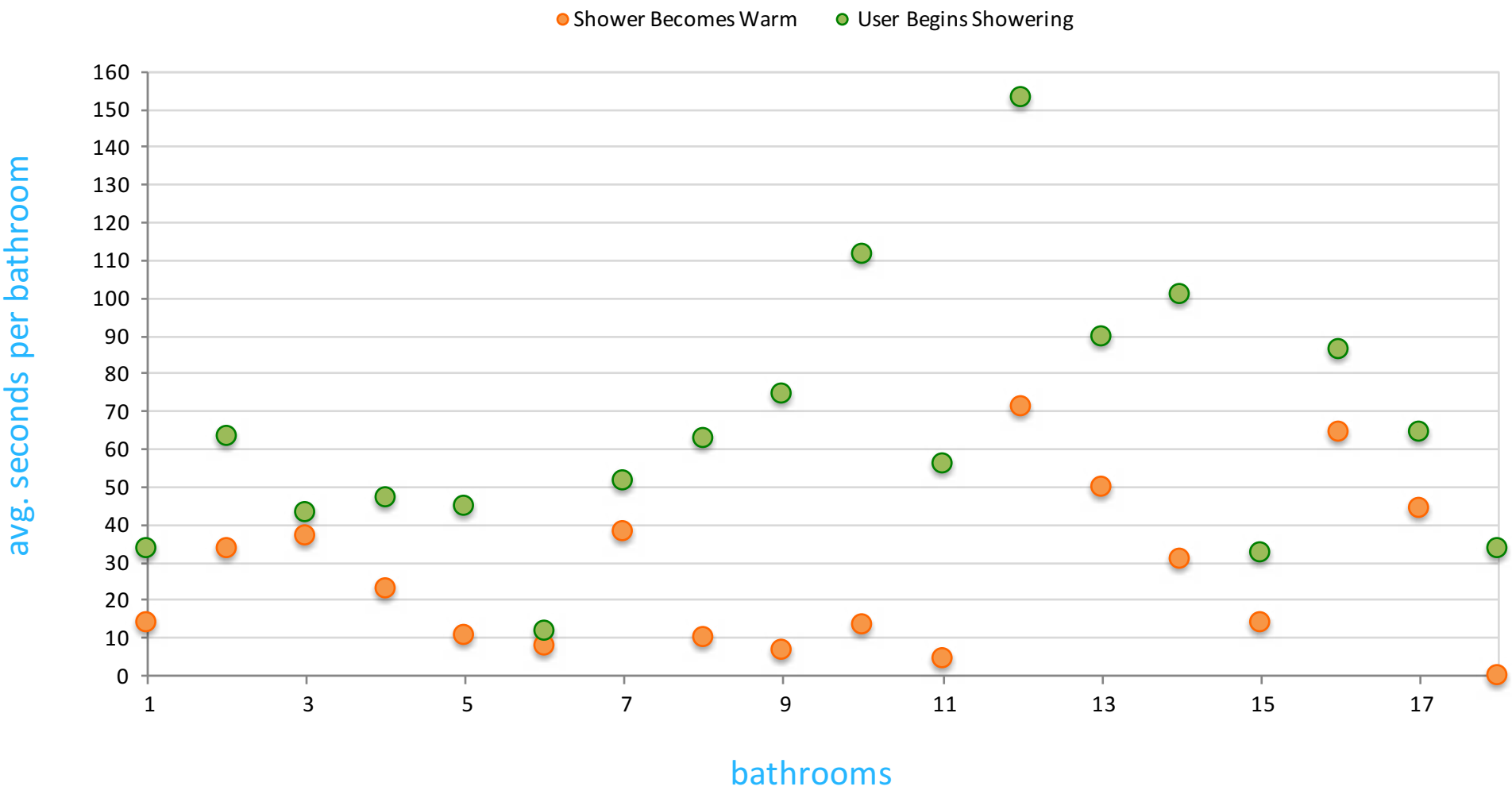

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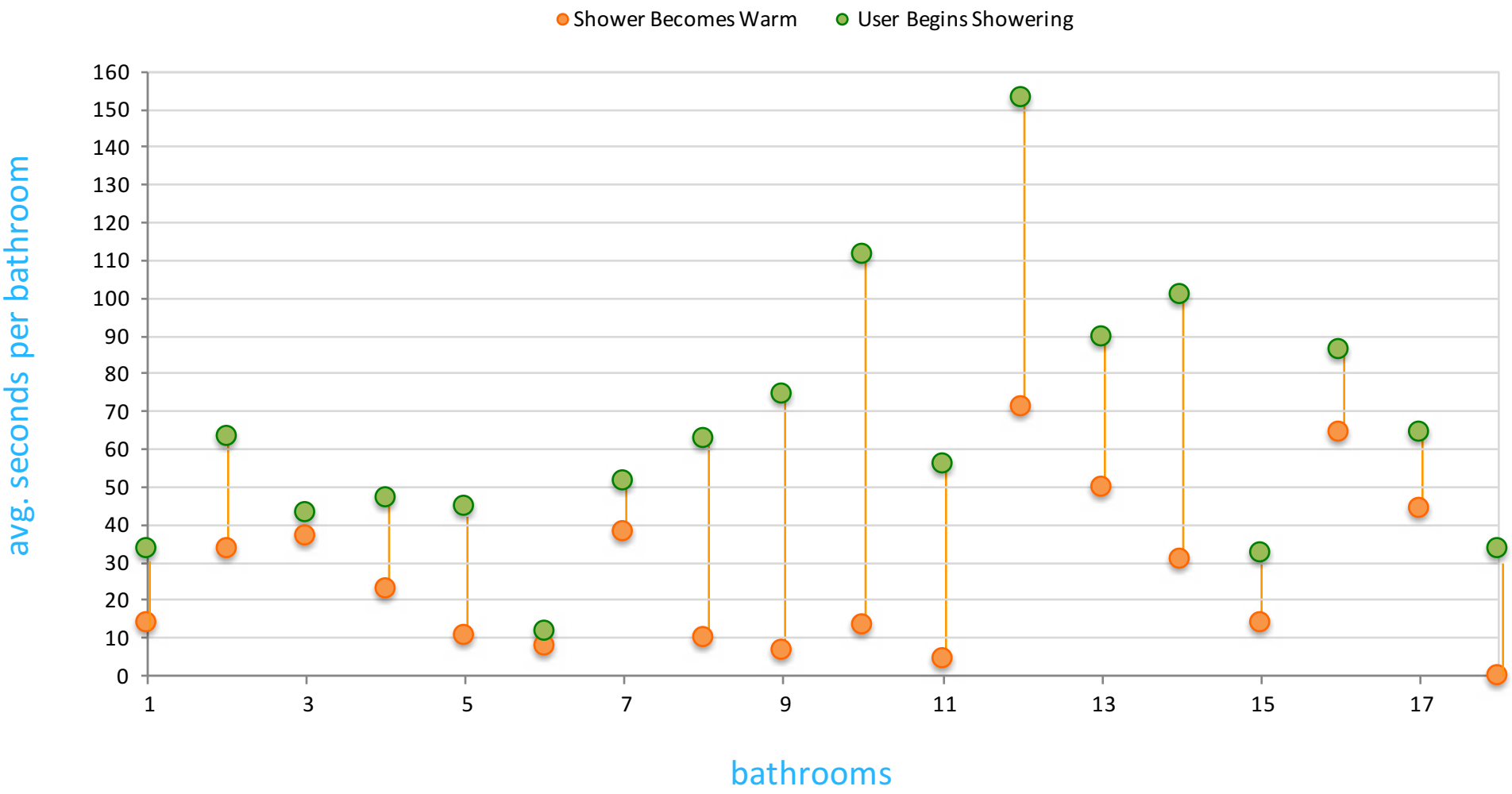

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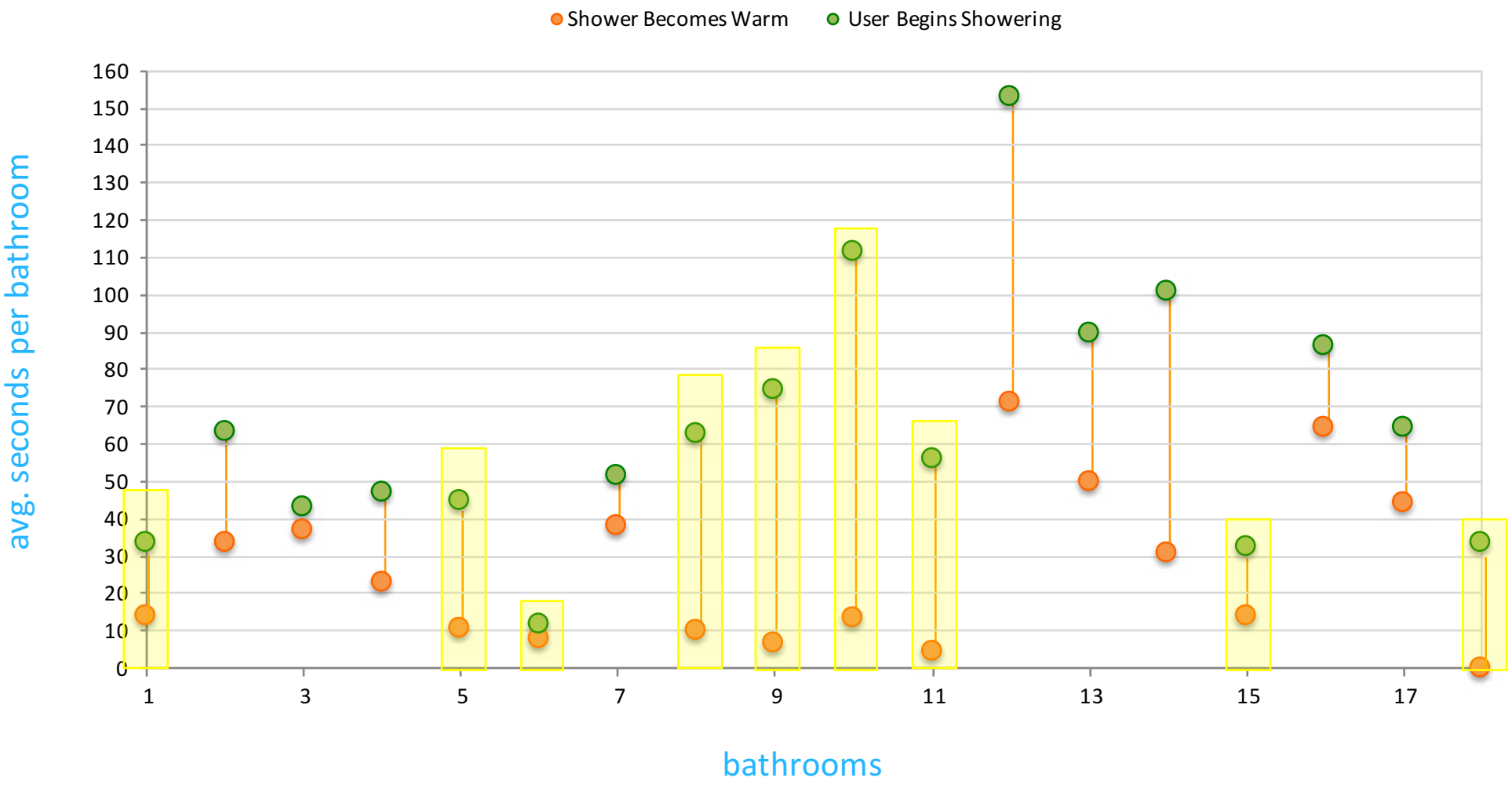

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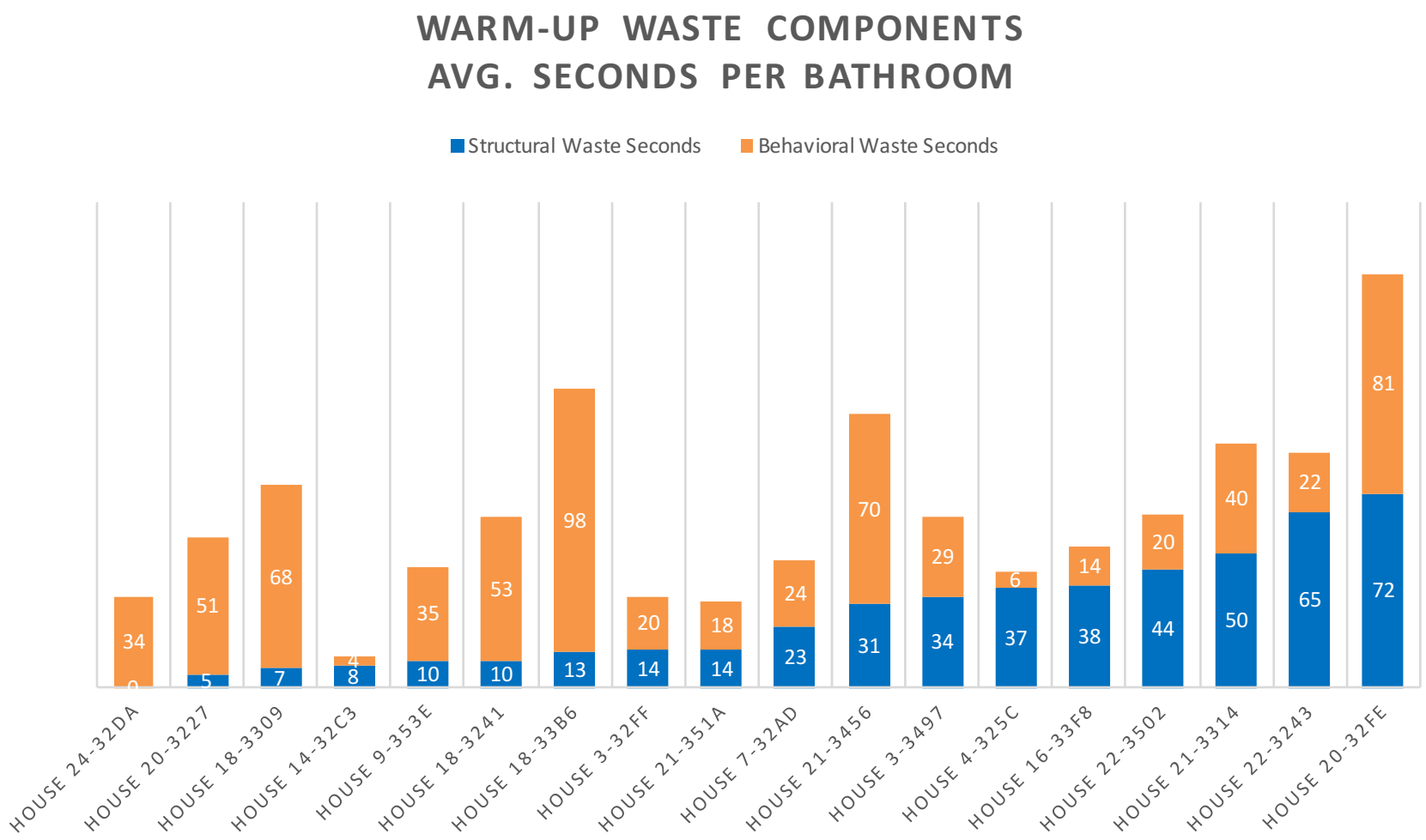

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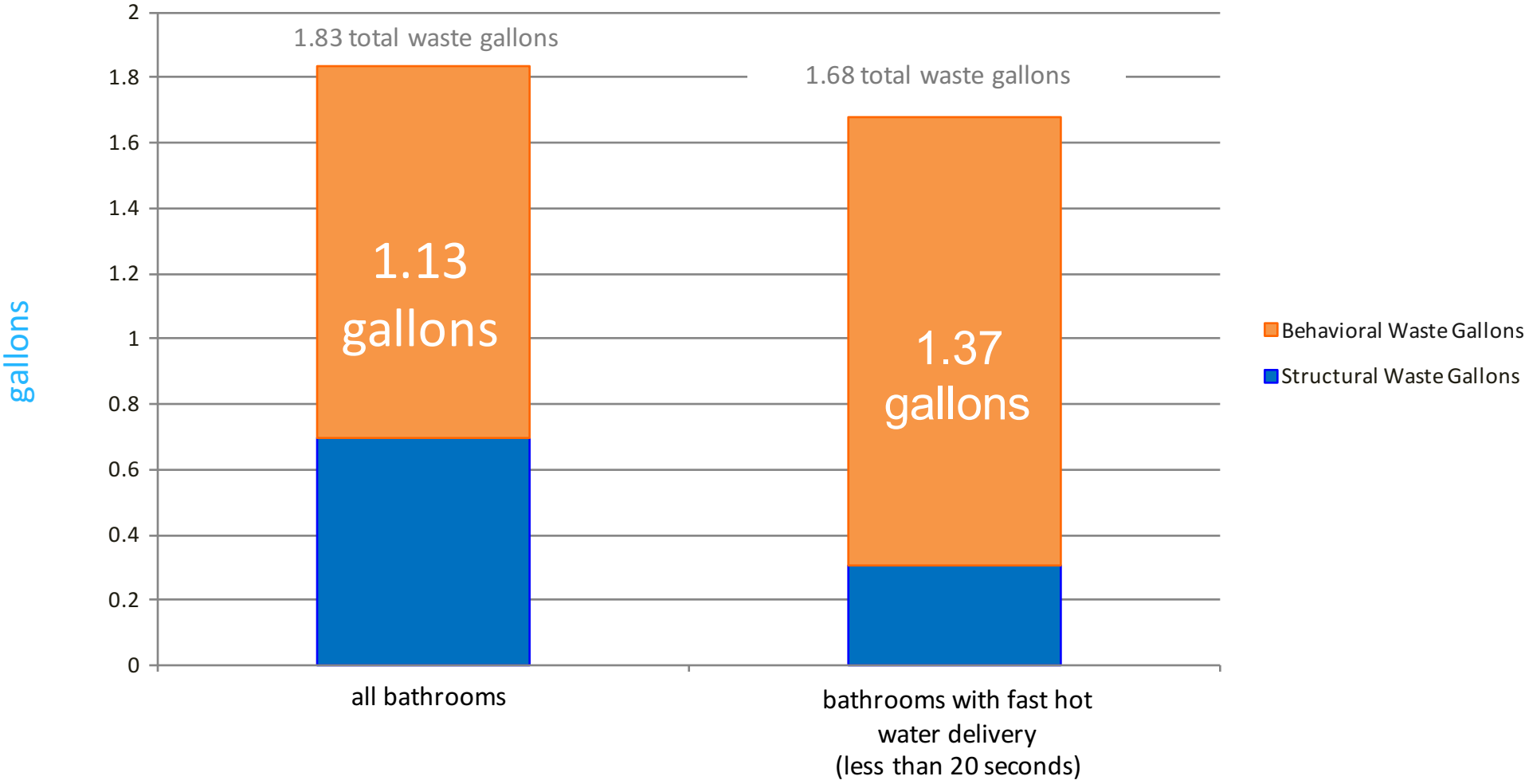
Fast Hot Water Delivery Increases Hot Water Waste

Fast hot water delivery increases average behavioral waste volume by +20%, while only reducing total average shower warm-up waste by 6%



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What's Going On Here?
Hot Water & Human Behavior

Changing Behavior Is Hard – Really Hard

Consider how

hard it is to change yourself

and you'll understand what

little chance

you have in trying to

change others.

- Benjamin Franklin

Have You Or A Family Member Ever _____ While Waiting For The Shower To Get Warm?

Most People Multitask While Waiting – Behavioral Waste

Behavioral waste occurs when bathers use their time comfortably and efficiently while waiting for hot water to reach the shower. Activities include brushing teeth, using the washroom, picking out clothes, drinking coffee …

71%

do other stuff while waiting for hot water to reach the shower

Evolve Technologies: Shower Survey 2008

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say routine, not presence of hot water, dictates time spent away from shower

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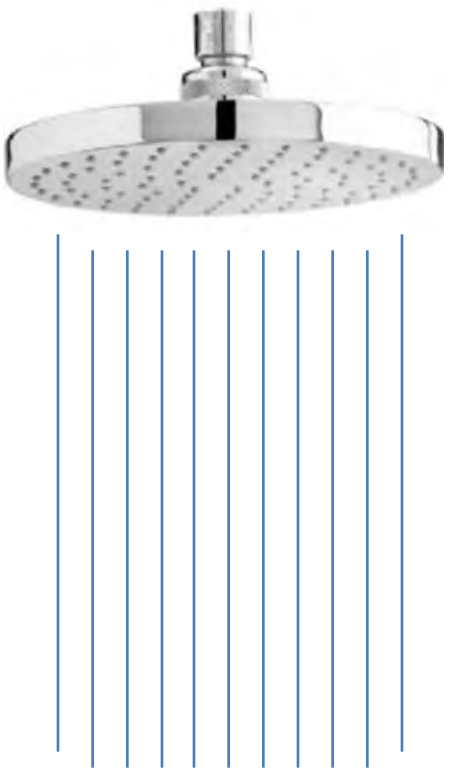
20% - 30% Of Shower Is Wasted Before Bathing Begins

In 2004 and 2011 papers Jim Lutz at Lawrence Berkeley National Lab indicates that shower warm-up waste falls in the 20% - 30% range.



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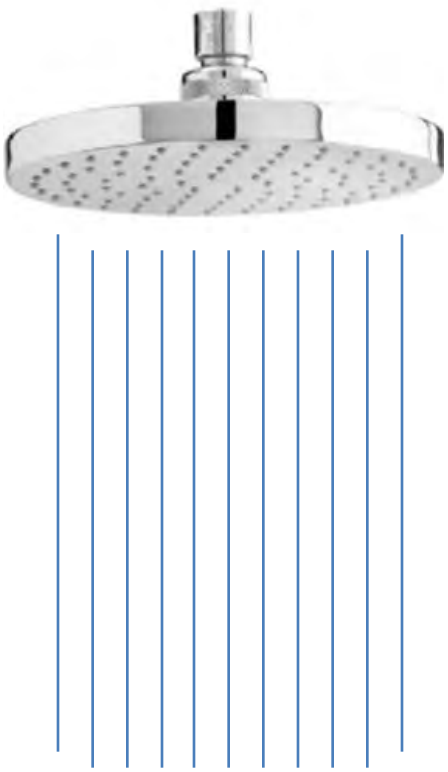

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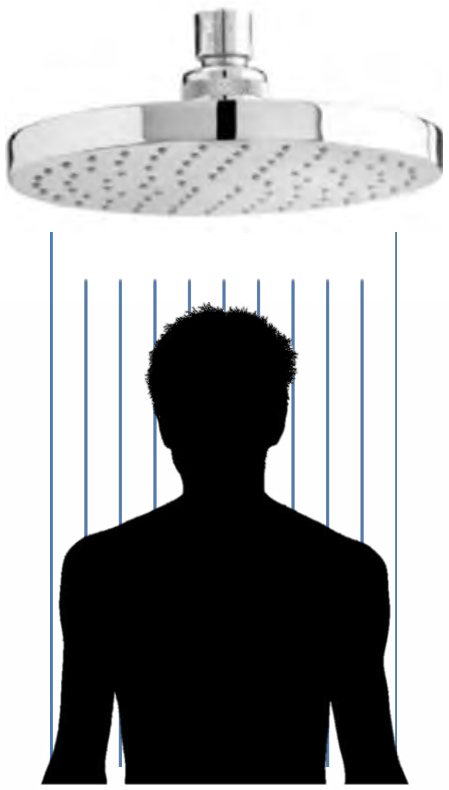

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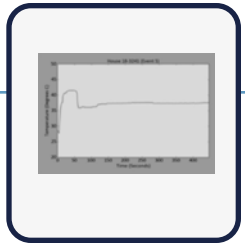

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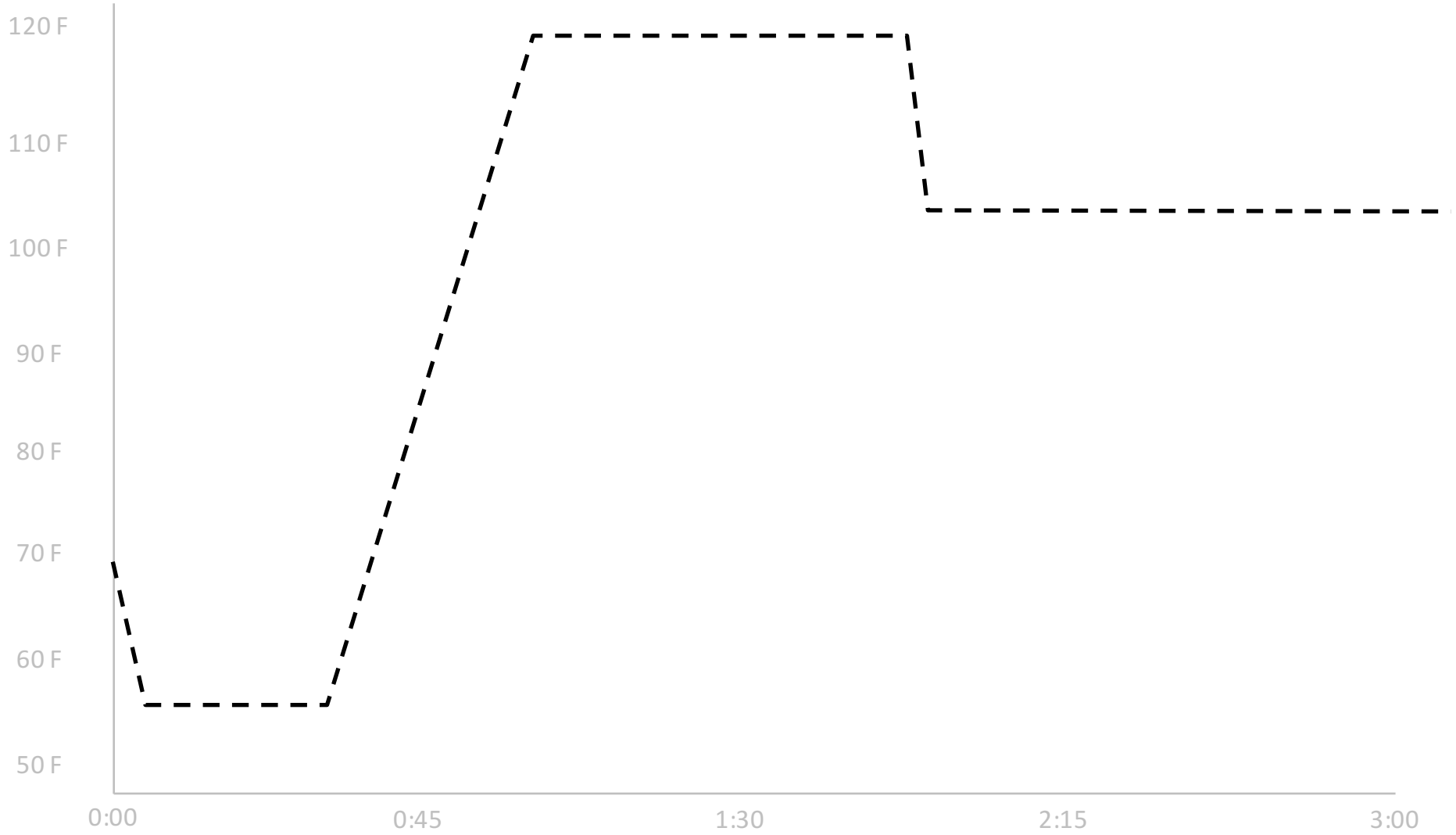

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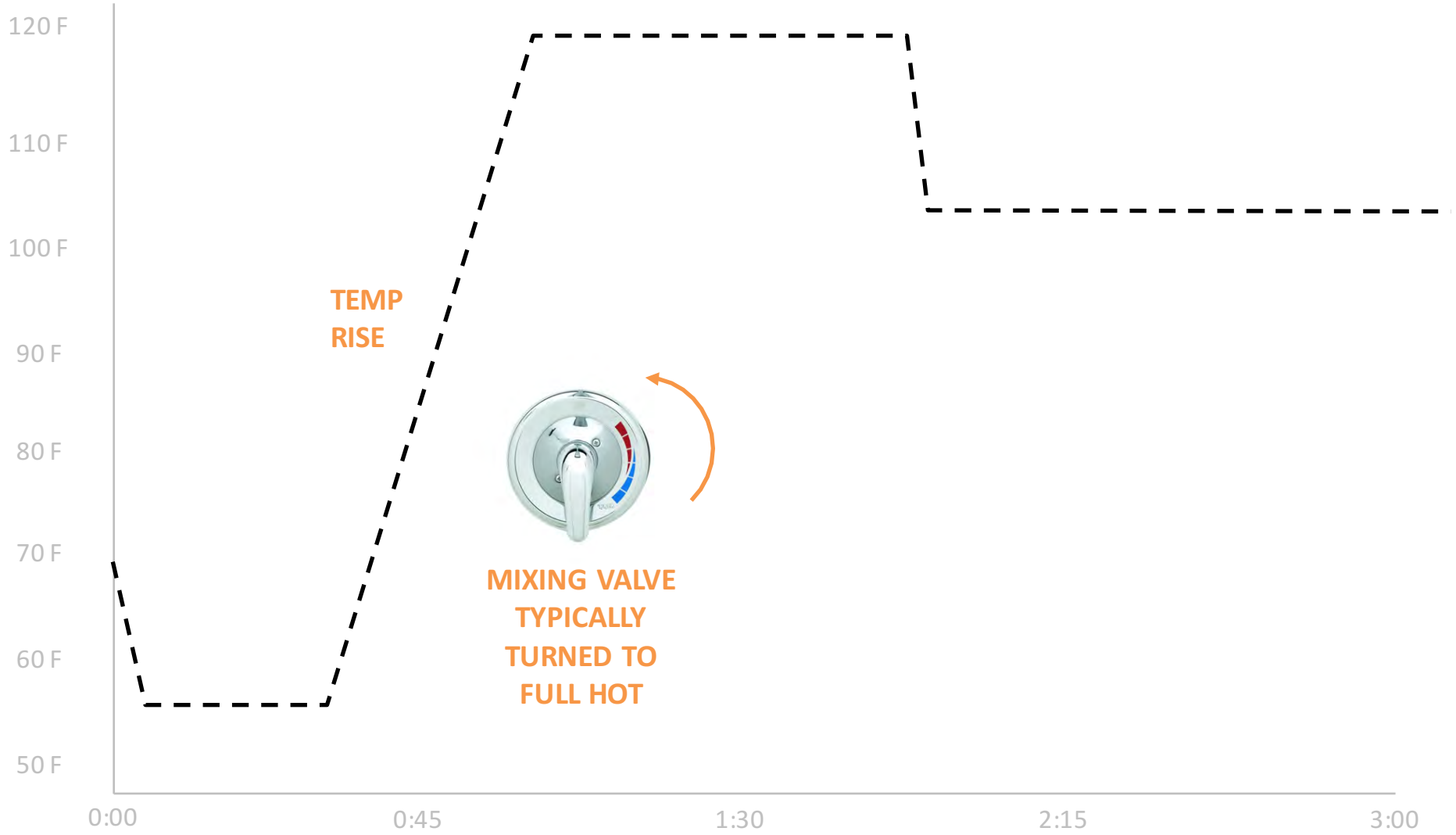

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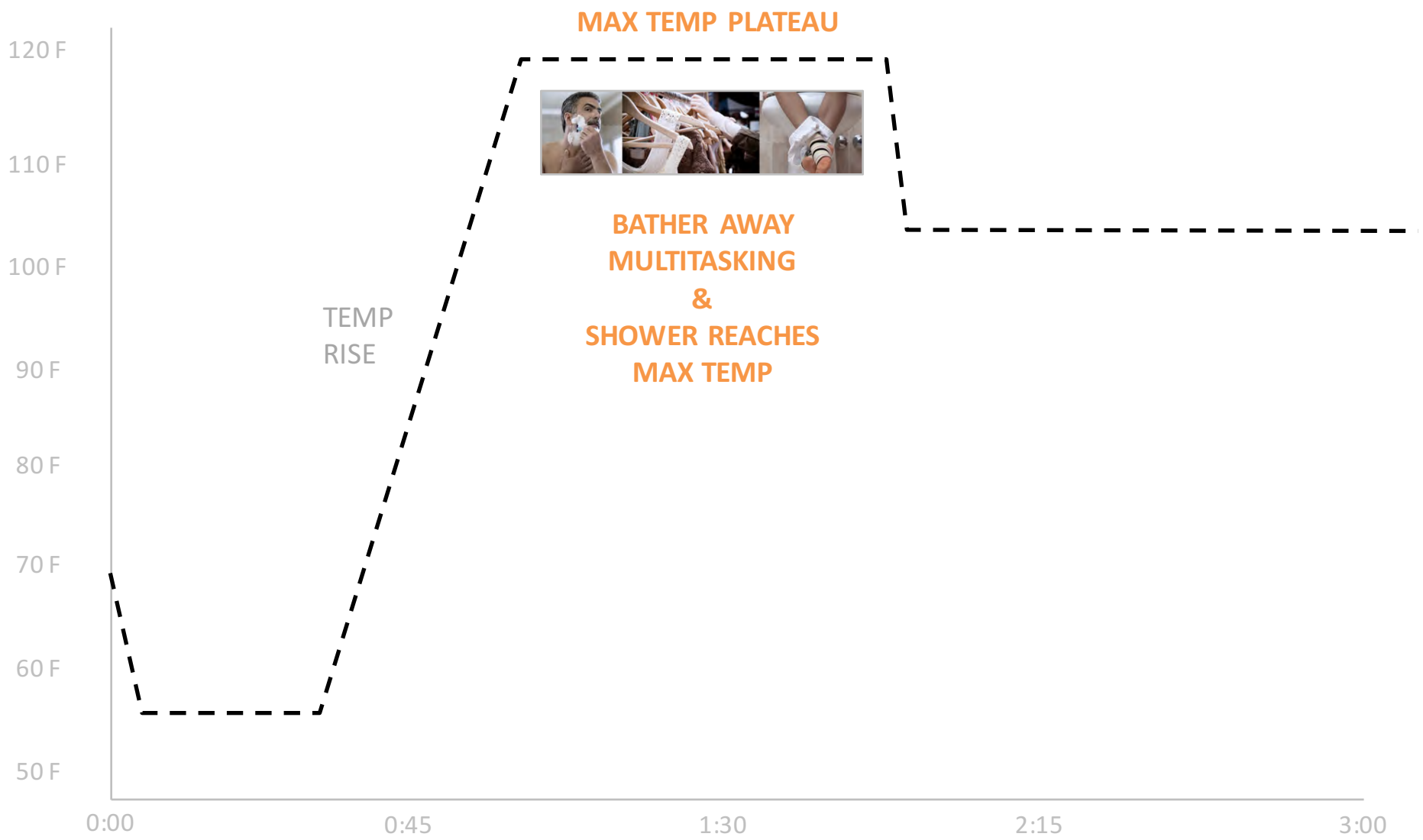

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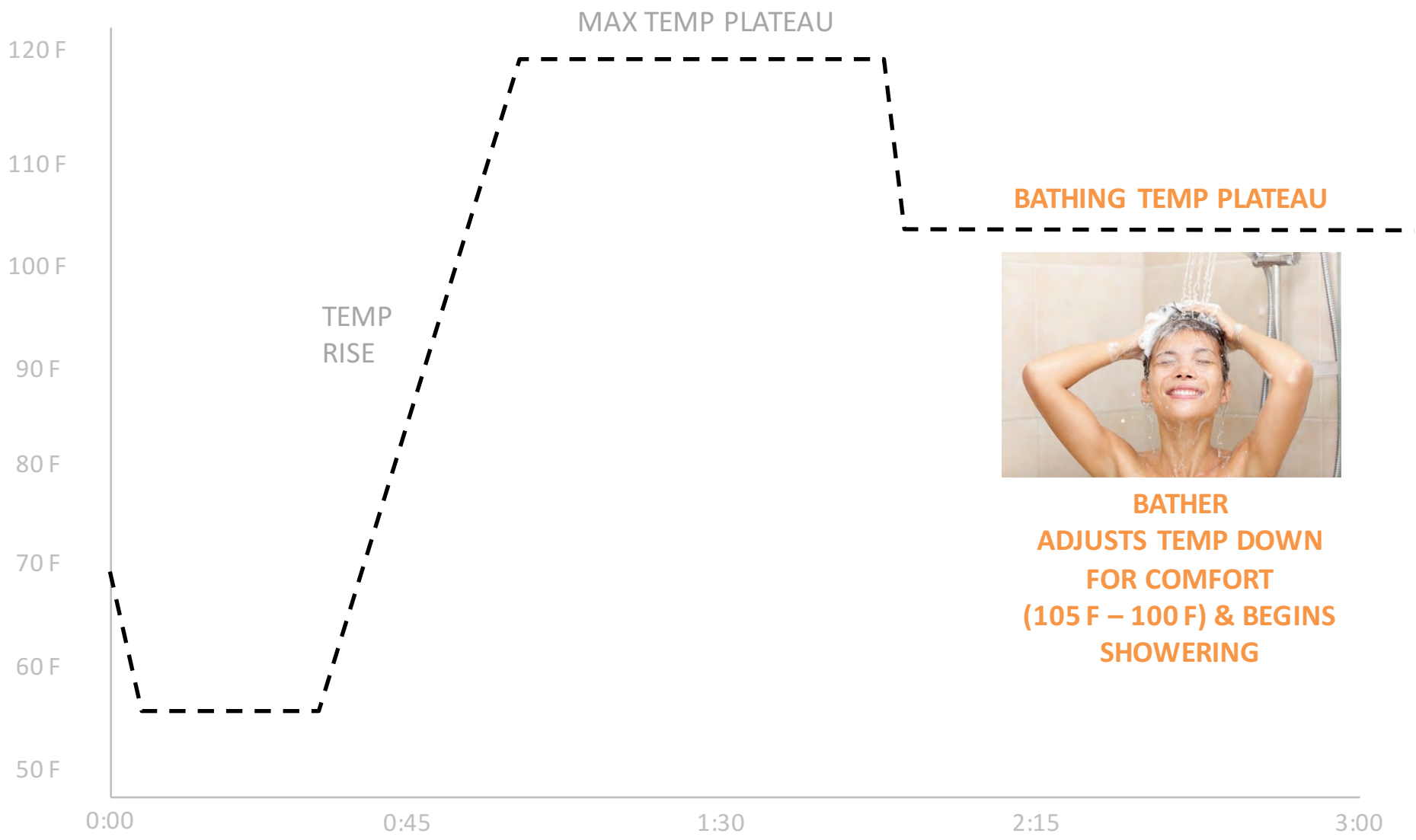

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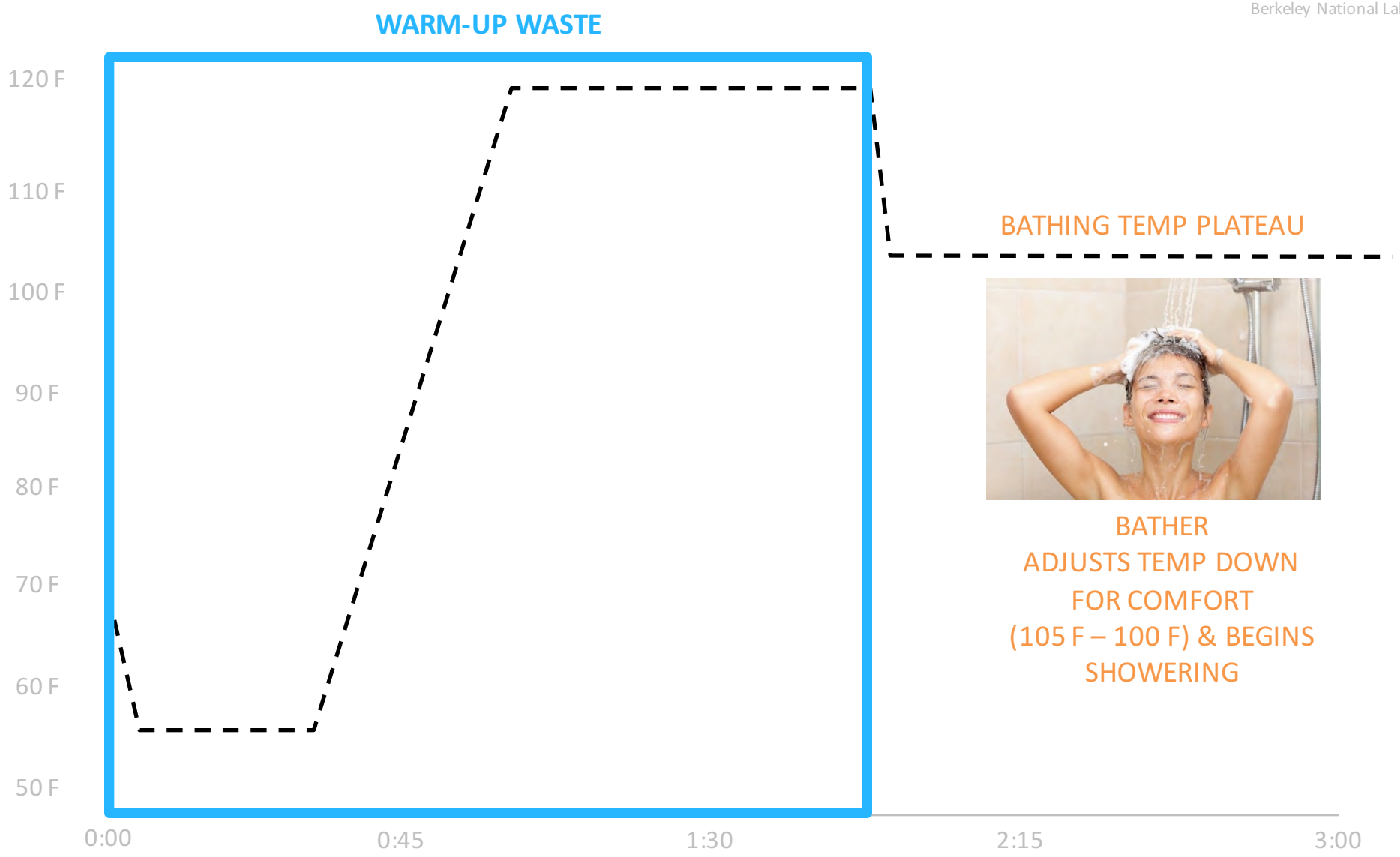

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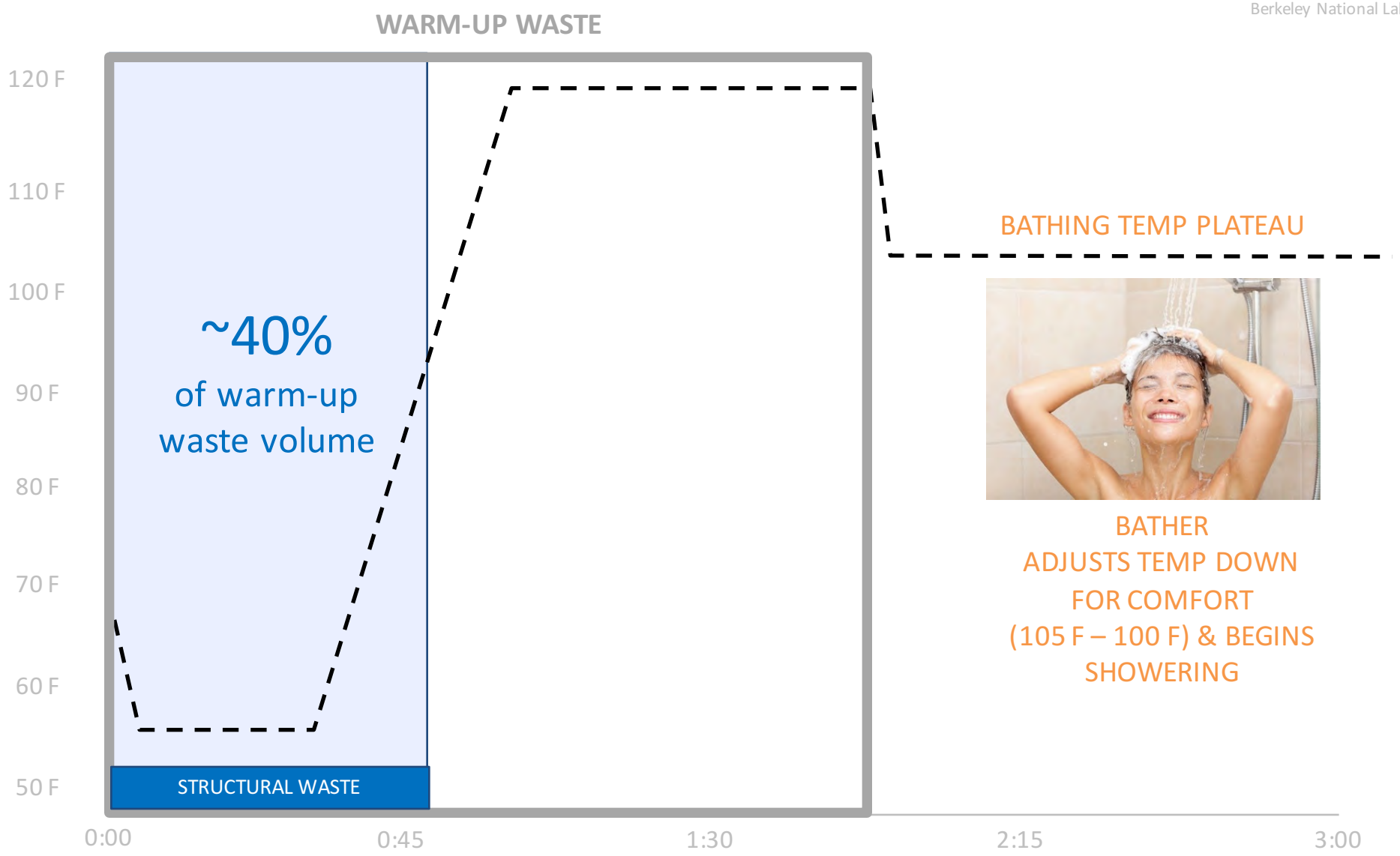

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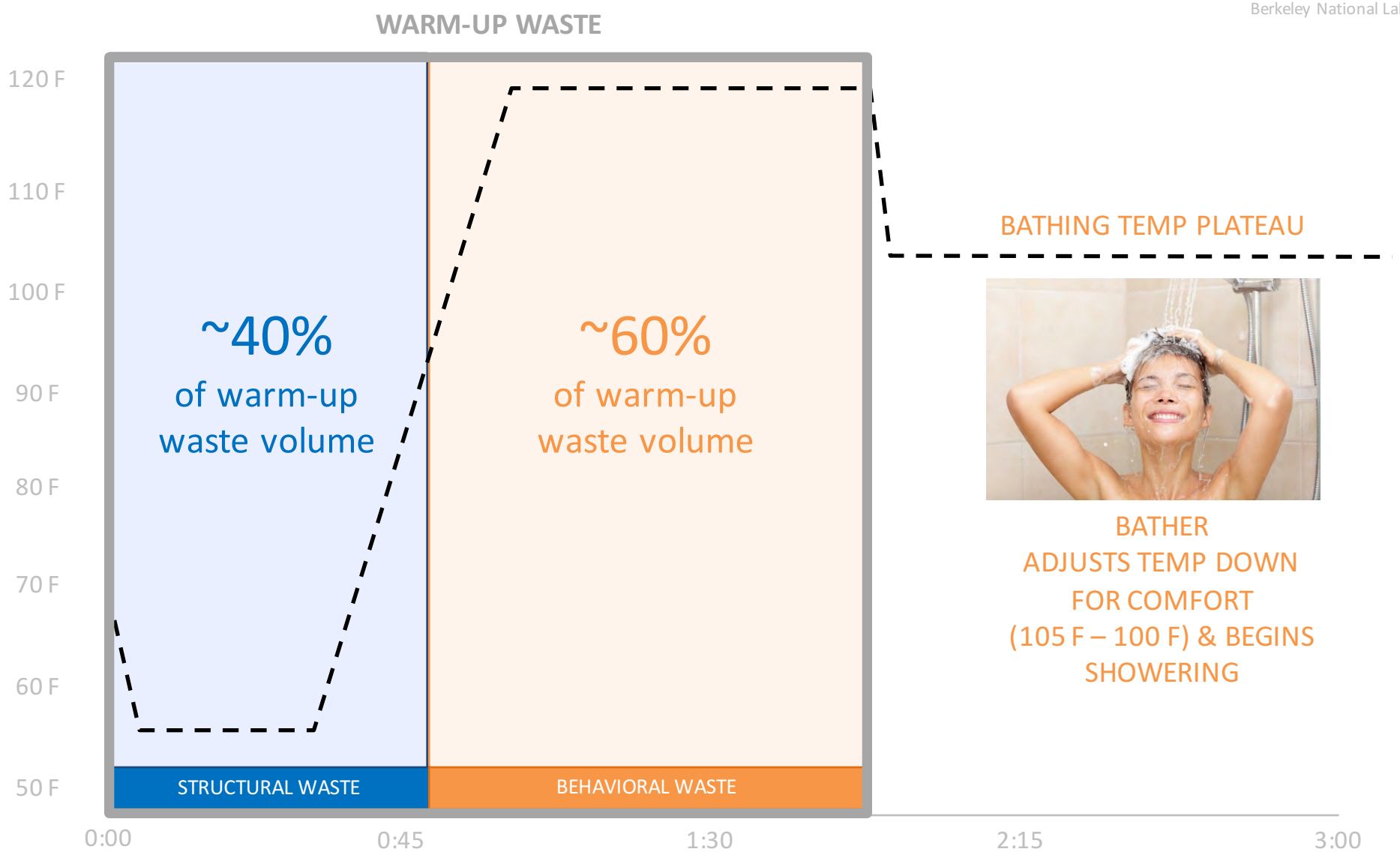
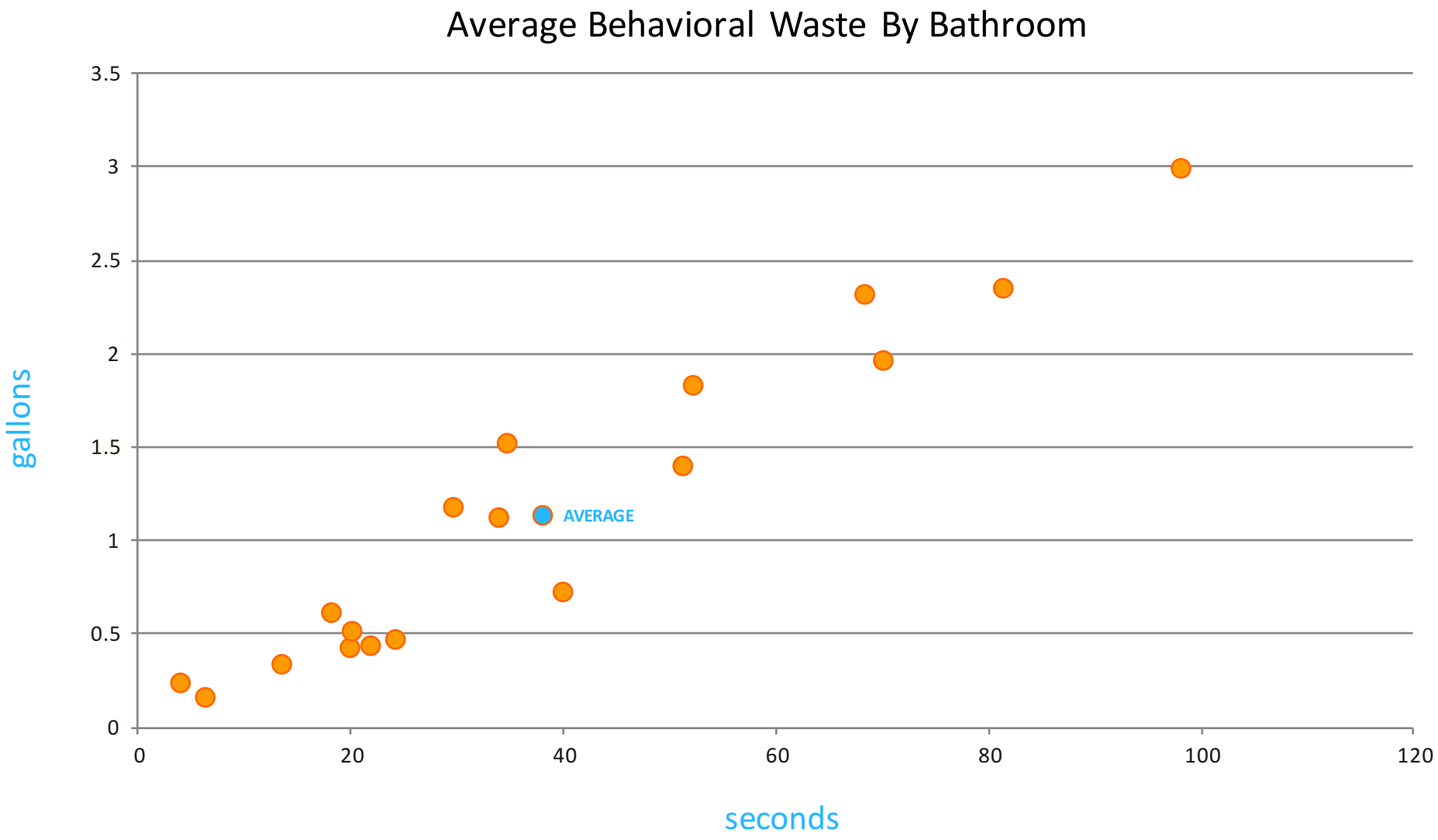


2013 LBNL Analysis - Some Waste A Little – Others Waste A Lot



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Behavioral Waste Estimates From '04 – '13 LBNL Analysis

Estimate range is inclusive of cold starts and clustered events.
Estimate range is based on LBNL work from 2004 – 2013.
Estimate is likely conservative as data was collected in one of the "greenest" regions of the country (SF Bay area).

38 seconds

Field Study

BEHAVIORAL WASTE RANGE

47 seconds average

56 seconds

95 sec of total waste from Lutz x
59% Behavioral Waste from field study

8 Month Multifamily 2014 Field Study In NC

2014 Greystar TSV evaluation in Raleigh, NC indicates average savings of 5 gallons per unit per day.
N=240 apartments: 120 unit test & 120 unit control

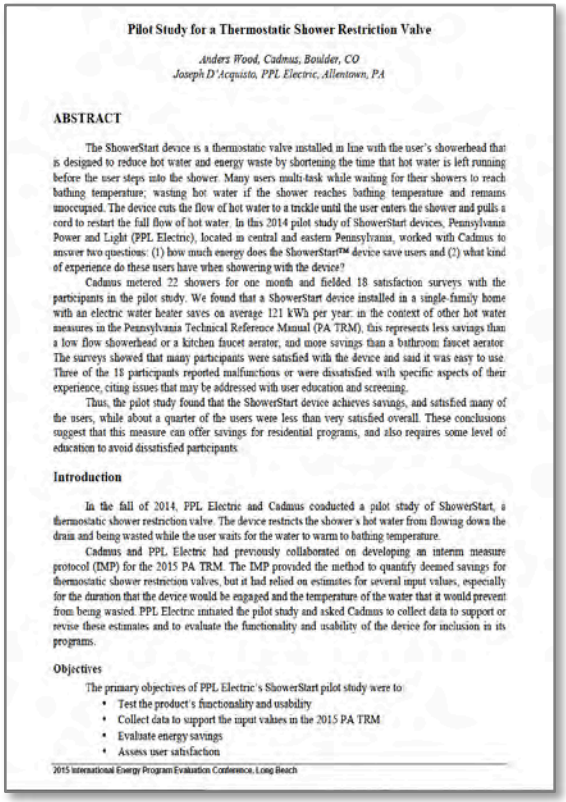
GREYSTAR
Redefining Excellence in Apartment Living.

5 gal
per day avg.
Hot Water Savings

~ 1 min

PPL Electric & Cadmus 2015 Field Study

2015 Pilot Study including 22 metered showers in 18 unique homes (581 events) for one month revealed average TSV savings of 59 seconds per shower.



Pilot Study for a Thermostatic Shower Restriction Valve

Anders Wood, Cadmus, Boulder, CO
Joseph D'Acquisto, PPL Electric, Allentown, PA

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

2015 International Energy Program Evaluation Conference, Long Beach

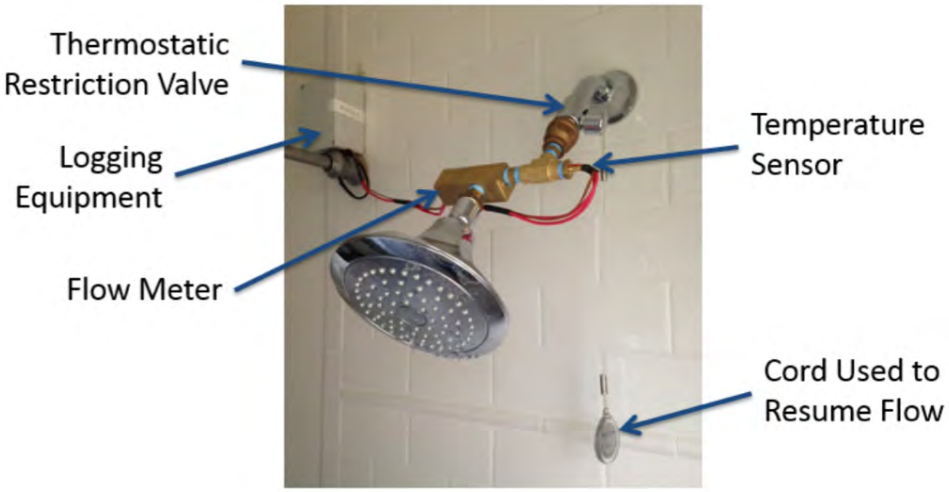


Table 4. Metering Results Summary

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

SOURCE: 2015 Pilot Study For A Thermostatic Shower Restriction Valve, Anders Wood (Cadmus) and Joseph D'Acquisto (PPL Electric)

Behavioral Waste Averages About A Minute Per Shower

BEHAVIORAL WASTE

What If Americans Could Eliminate Behavioral Waste …

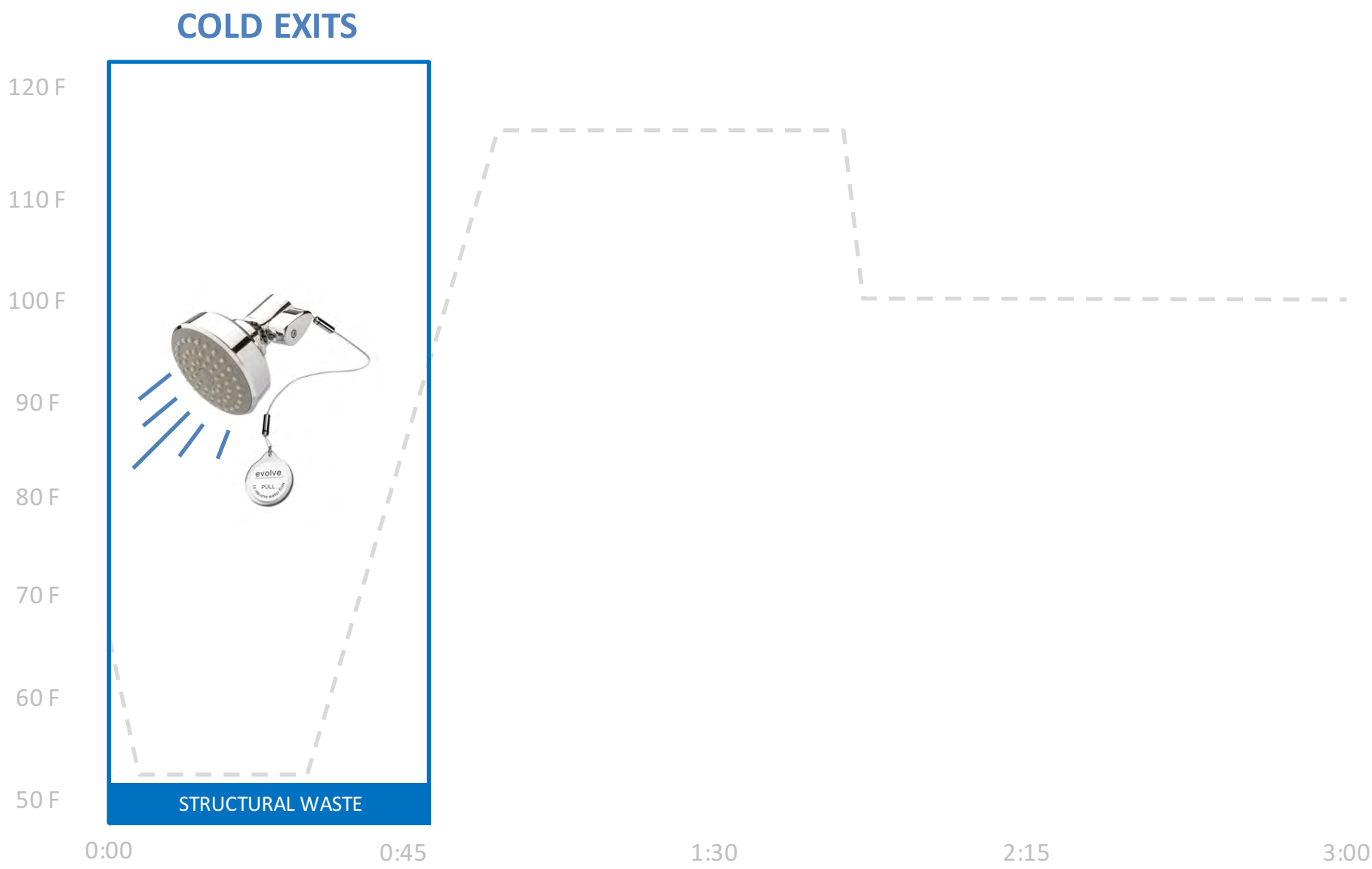
Without Changing Behavior or Making Sacrifices?

The Thermostatic Shut-Off Valve (TSV) Solution

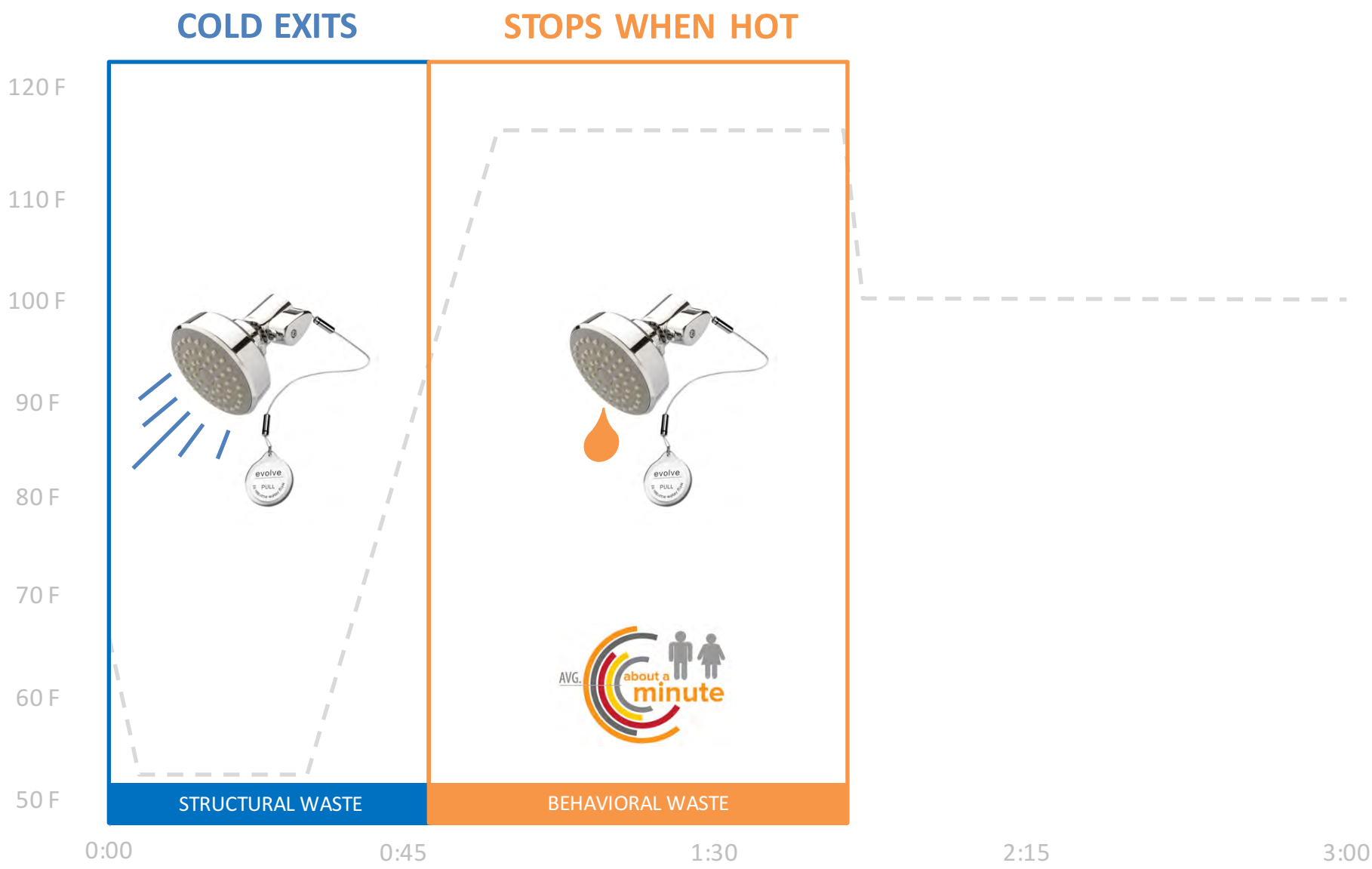
Keep Your Routine – Save Your Hot Water

- Eliminates Behavioral Waste – Saves the water and energy most bathers don't even realize they're wasting.
- Savings occur without changing shower flow, feel or even your morning routine.

How A TSV Works



How A TSV Works



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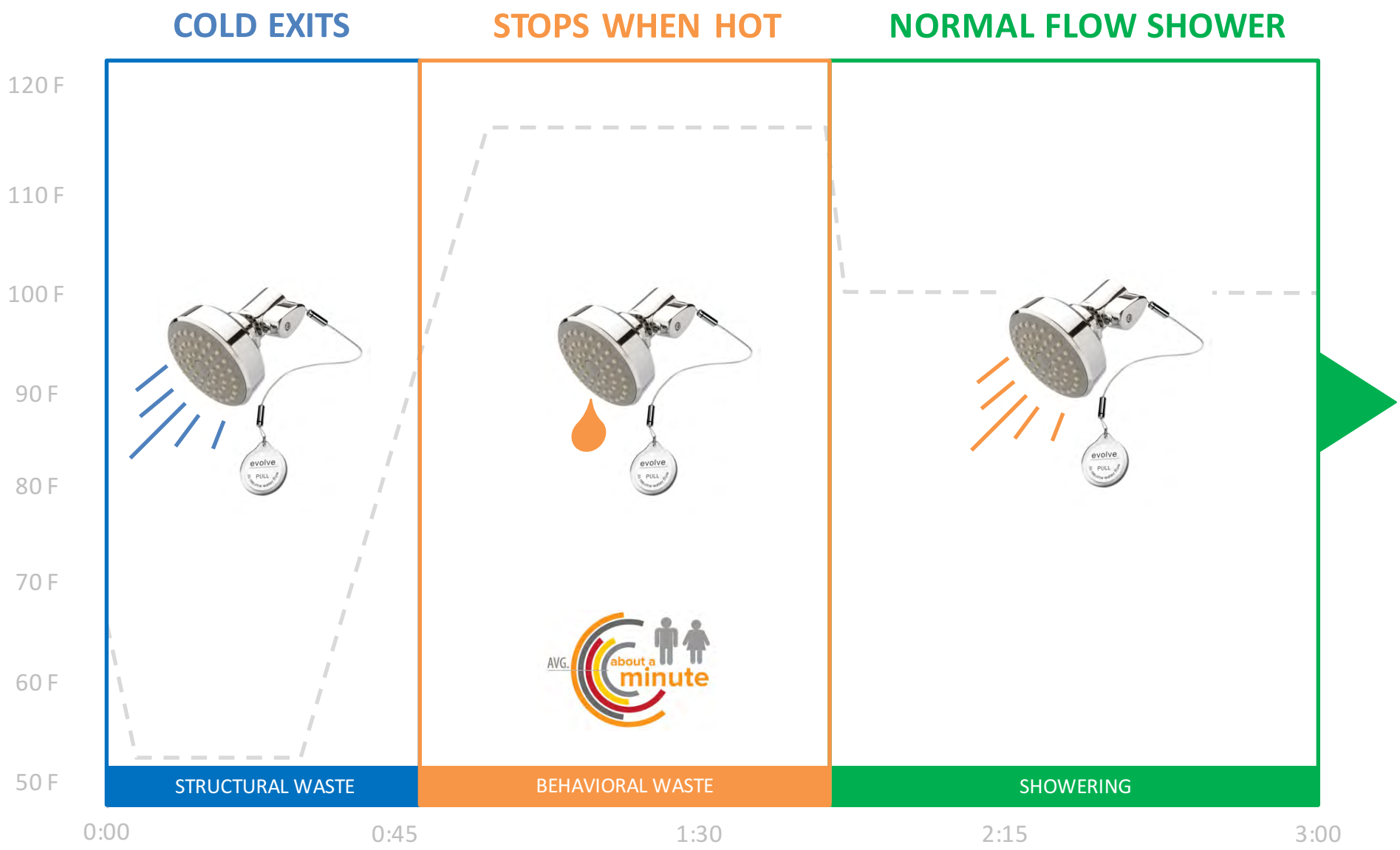

The Annual Benefit Of Eliminating Behavioral Waste In The USA

168 Billion

Gallons Water/Year

in USA

9 years

of drinking water for everyone in USA

(58 gallons person/year)

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Therms/Year

in USA

1.3 MM cars

gasoline fueled for a year

(13K miles per year @ 25 mpg)

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1.3 MM cars
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or

18.5 Billion
kWh/Year
in USA

1.6 MM homes
electricity consumption for a year
(11,320 kWh home/year)

What Happens If We Start …

Thinking About Bathing As A System

Most Showers Take Place In A Tub Shower Combo

Tub Spout warm-ups, multitasking during the warm-up and leaky tub spouts are commonplace.

62%

TUB/SHOWER COMBOS

648 of the people surveyed reported that they typically shower in a tub/shower combination unit

40%

TUB SPOUT WARM UP

258 people with tub/shower combo units warm their shower by letting the water run through the tub spout and activating the diverter AFTER the water becomes warm

58%

MULTITASK

149 people doing tub spout warm ups regularly or occasionally leave to do something else while waiting for the water to become warm

SOURCE: 2014 Evolve Technologies Warming Your Shower Survey

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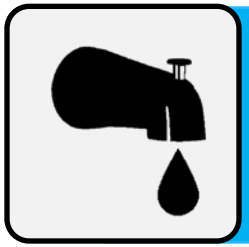


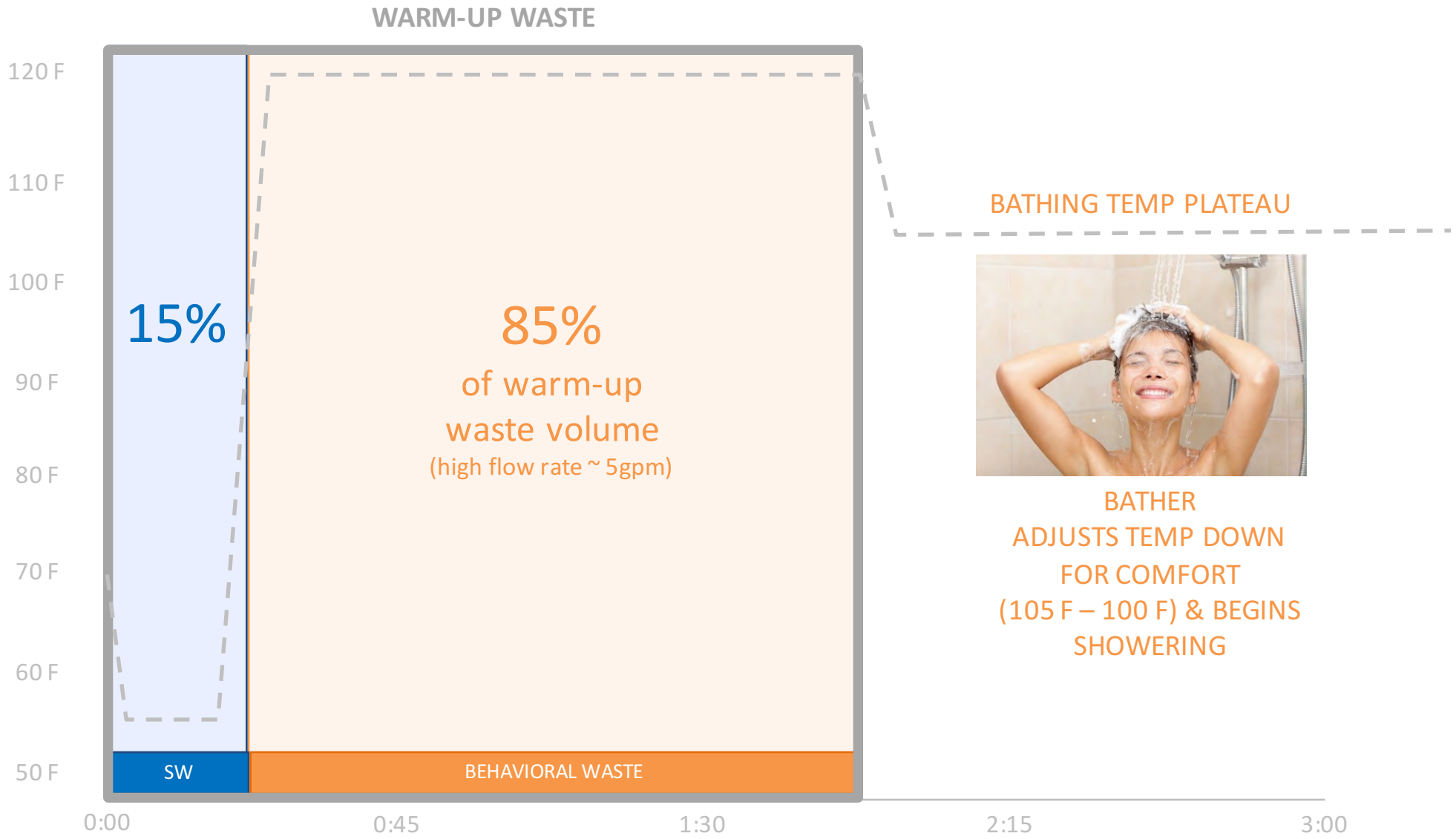
34%

LEAKY TUB SPOUT

220 showering in a tub/shower combo unit report that their tub spout leaks during their showers

SOURCE: 2014 Evolve Technologies Warming Your Shower Survey

Anatomy Of A Tub Spout Warm-Up



What Happens When You Marry A TSV To A Tub Spout

+

Auto-Diverting Tub Spout System

The Benefits Of A Systematic Approach – The Most Convenient And Efficient Showering System Available

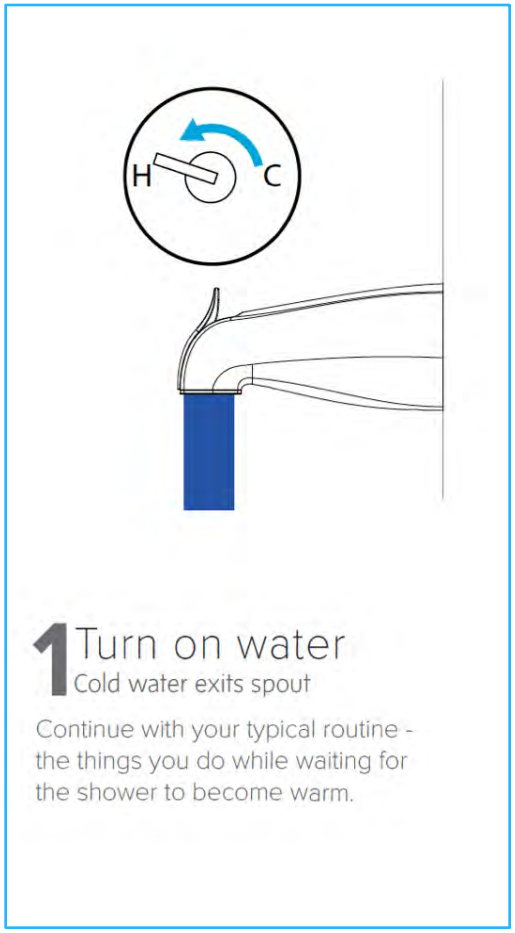
Most Convenient

- **Greatly Reduces Wait Times**
  Structural waste is purged significantly faster because of higher flow rates and fluid dynamics
- **Automatically Diverts Hot Water To Showerhead**
  Sends hot water to showerhead once it arrives at tub spout

Most Efficient

- **Reduces Structural Waste**
  Structural waste volume is reduced as a result of "plug flow" at higher flow rates
- **Eliminates Behavioral Waste**
  Stops hot water from running down drain when user is away from shower during warm-up
- **Anti Leak Tub Spout Design**
  Tub spout leaks during shower can waste up to 5.5 gallons or more per shower
- **More Efficient Shower**
  A specialized WaterSense showerhead is part of the system

Auto-Diverting Tub Spout System – How It Works



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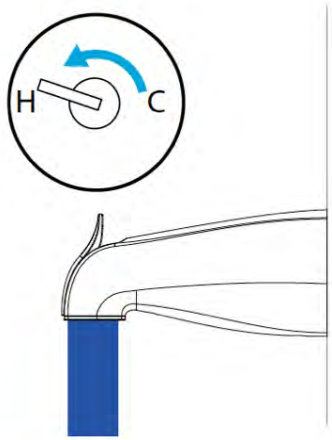
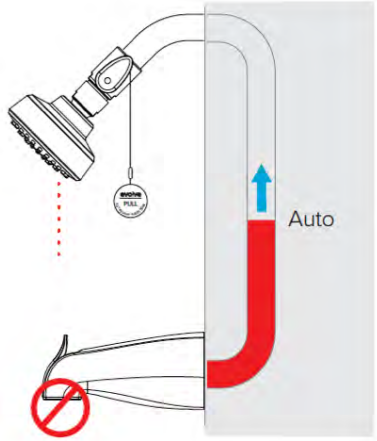


1 Turn on water
Cold water exits spout

Continue with your typical routine - the things you do while waiting for the shower to become warm.



2 Auto diverts when hot water arrives

Upon reaching 95°F, ShowerStart Technology automatically diverts flow. Showerhead trickles - saving hot water until you get in.

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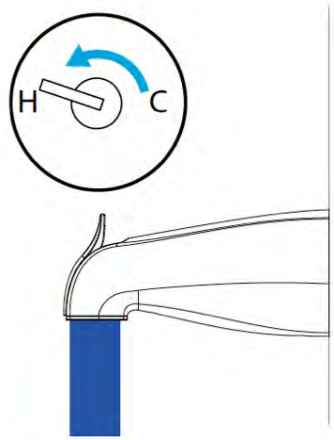

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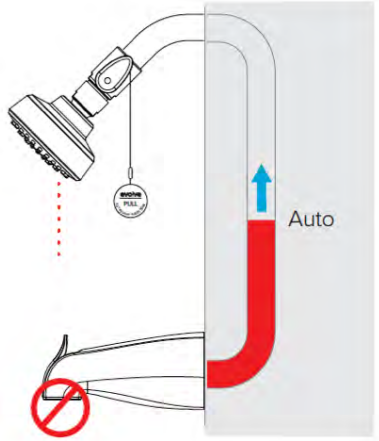

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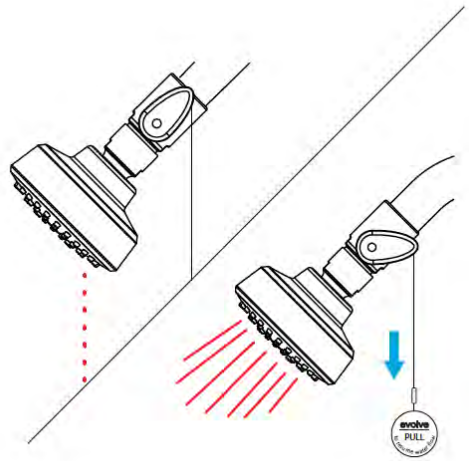

3 Pull cord when ready to get in

Pull the cord to activate normal flow and begin showering.

Unique Water & Energy Savings Opportunities With System Solution

.4 GALLONS SAVED

Structural Waste

SOURCE: Calculating Savings For Auto-Diverting Tub Spout System With ShowerStart TSV, December 2015

Unique Water & Energy Savings Opportunities With System Solution

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5.1 GALLONS SAVED

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Efficient Showering

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Structural Waste

5.1 GALLONS SAVED

Behavioral Waste

5.0 GALLONS SAVED

Efficient Showering

4.5 GALLONS SAVED

Anti-Leak Tub Spout

15 GALLONS SAVED PER SHOWER

SOURCE: Calculating Savings For Auto-Diverting Tub Spout System With ShowerStart TSV, December 2015

TSVs Guarantee The Benefits of Improved Plumbing Design

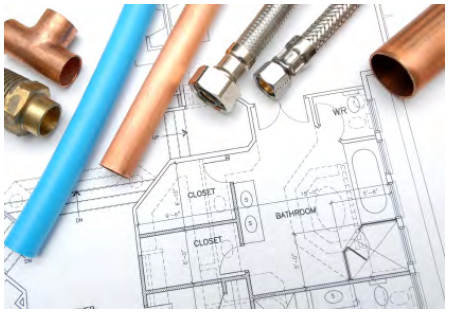
Behavior is persistent and a Thermostatic Shut-Off Valve is necessary to guarantee the assumed effectiveness of improved plumbing design.

TSV

Auto-Diverting
Tub Spout

GUARANTEE

Without a TSV compact plumbing may actually increase water and energy consumption.



compact plumbing designs (efficient)

Comparative Savings

TSV

Therms

4 – 7

kWh

95 – 160

Gallons

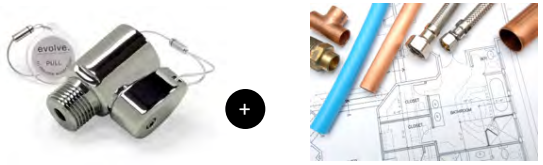
880 - 1,460

ASSUMPTIONS: 1 Min Behavioral Waste, 57F inlet, 105F temp, .76 gas recover efficiency, 2.56 people per household, .625 showers person/day , 1.5 – 2.5 gpm flow rates, improved plumbing saves 90% of structural waste. Auto Diverting Tub-Spout System savings estimate based on calculations from SoCalGas & Navigant Consulting.

Comparative Savings

50%
Greater Savings

TSV



TSV +
Improved Plumbing

	TSV	TSV + Improved Plumbing
Therms	4 – 7	6 – 10
kWh	95 – 160	140 – 235
Gallons	880 - 1,460	1,320 - 2,190

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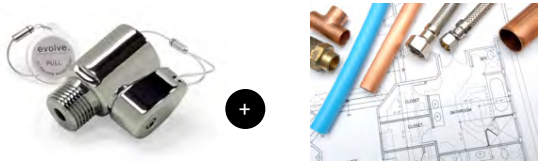
Comparative Savings

50%
Greater Savings

350%
Greater Savings

ShowerStart TSV



TSV +
Improved Plumbing

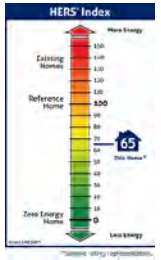
Auto-Diverting
Tub Spout System

	ShowerStart TSV	TSV + Improved Plumbing	Auto-Diverting Tub Spout System
Therms	4 – 7	6 – 10	18 – 32
kWh	95 – 160	140 – 235	415 – 740
Gallons	880 - 1,460	1,320 - 2,190	8,687

ASSUMPTIONS: 1 Min Behavioral Waste, 57F inlet, 105F temp, .76 gas recover efficiency, 2.56 people per household, .625 showers person/day , 1.5 – 2.5 gpm flow rates, improved plumbing saves 90% of structural waste. Auto Diverting Tub-Spout System savings estimate based on calculations from SoCalGas & Navigant Consulting.

TSVs Are Accepted And Used In Nation's Largest Efficiency Programs

- + 1MM units installed in single family and multifamily homes via the largest IOU EE & weatherization programs in the country.
- Inclusion in RESNET's updated HERS scoring method.
- Inclusion in Build It GREEN's updated Green Point energy and water calculator.



Consequences
Of Non-System Thinking

Popular Efficiency Products - Consider The Unintended Consequences

Products that appear to save may actually increase use due to the way they function within the system or impact user behavior within the system.

tankless water heaters

CONSEQUENCE:
longer hot water waits

POTENTIAL RESULT:
increased multitasking & behavioral waste

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efficient showerheads

CONSEQUENCE:
longer hot water waits

POTENTIAL RESULT:
increased multitasking & behavioral waste

on demand pumps

CONSEQUENCE:
behavior change required for its effectiveness

POTENTIAL RESULT:
increased hot water use

Acceptance Opportunities

Opportunities For Improved Efficiency – A Paradigm Shift

The most widely used products in today's efficiency programs fall within the FORCED CHANGE category. Meaningful long-term savings and higher resident satisfaction geared towards comfort and convenience can be achieved by focusing on the NO CHANGE category.

high

PRODUCT PERSISTANCE & USER SATISFACTION (NEBs)

low

low flow showerhead

FORCED CHANGE
product compels lower consumption by altering user experience

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high

PRODUCT PERSISTANCE & USER SATISFACTION (NEBs)

low

energy use report/comparison

VOLUNTARY CHANGE
information elicits voluntary behavior change to reduce consumption

low flow showerhead

FORCED CHANGE
product compels lower consumption by altering user experience

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PRODUCT PERSISTANCE & USER SATISFACTION (NEBs)

high

low

TSV

Improved Plumbing

NO CHANGE
technology reduces consumption without need for altered experience or behavior change

energy use report/comparison

VOLUNTARY CHANGE
information elicits voluntary behavior change to reduce consumption

low flow showerhead

FORCED CHANGE
product compels lower consumption by altering user experience

Conclusions

- DHW is increasingly becoming a larger and larger portion of home energy consumption.

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- The most efficient and cost effective place to tackle DHW consumption is in the shower.
- Don't under estimate the importance of mitigating the behavior variable.

- System thinking leads to dramatic savings opportunities while increasing customer convenience and satisfaction.

Thank You

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480.250.4563