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SERVICE & DOMESTIC HOT WATER

DIVERTING TUB SPOUT WITH TSV

SWWH023-01

CONTENTS

MEASURE NAME

Diverting Tub Spout with Thermostatic Shut-off Valve (TSV)

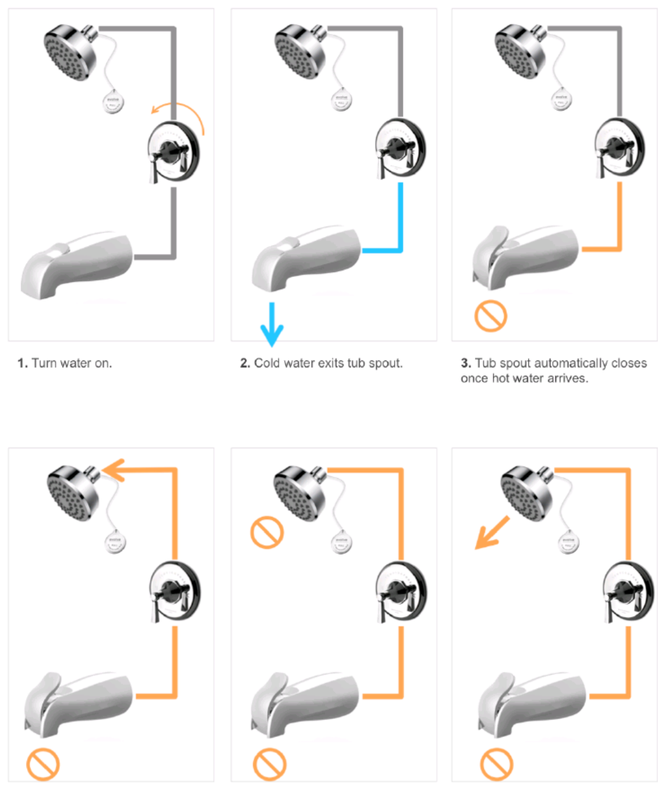
STATEWIDE MEASURE ID

SWWH023-01

TECHNOLOGY SUMMARY

Consumer behavior is a significant driver of water and energy waste due to shower warm-ups and leaky tub spouts.[1] An auto-diverting tub spout (ADTS) with a thermostatic shut-off valve (TSV) is a replacement for tub spouts and showerheads in residential dwellings with a shower-bathtub combination. The ATDS with a TSV reduces structural waste, diminishes behavioral waste,[2] stops tub spout leakage,[3] and reduces the showerhead flow rate to 1.5 gpm.

These benefits are realized with a flow diverter and TSV within the tub spout that detects when water reaches 95 °F. The technology purges the cold water in the shower piping through the spout causing faster hot water arrival water with less water (structural waste). Once the hot water arrives, the diverter changes the flow direction to the showerhead where the water flow is reduced to a trickle with no tub spout leak. The user then pulls the lanyard on the showerhead to open the valve and allow normal water flow.



1. Turn water on.

2. Cold water exits tub spout.

3. Tub spout automatically closes once hot water arrives.

4. Hot water is automatically diverted to specialized showerhead (integrated normally closed valve).

5. Specialized showerhead trickles by default so hot water is not flowing until user is ready to shower.

6. User pulls cord to activate specialized showerhead's normal flow and begins showering.

[1] Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC.

Taitem Engineering. 2011. "Leaking Shower Diverters." *Tech Tip, New York State Homes & Community Renewal.*

[2] Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC.

[3] Taitem Engineering. 2011. "Leaking Shower Diverters." *Tech Tip, New York State Homes & Community Renewal.*

Studies pertinent to the analysis of this technology include:

Disaggregating Residential Shower Warm-Up Waste. An Understanding and Quantification of Behavioral Waste Based On Data from Lawrence Berkeley National Lab (Sherman, 2014).[4] This study quantifies structural waste and behavioral waste time frames due to shower warm-ups in single family homes from survey data collected from 1,057 single family residents and 19 homes monitored throughout California The data and findings from this study helped to establish the baseline consumption and water savings. The average flow rate of the dedicated showers and tub/shower combinations documented in the study was 1.79 gpm. This lower-than-average flow rate indicates the study participants were likely to be more conservation oriented than average and, as a result, could be producing less total warm-up waste than a typica household. This study did not include multifamily residences but is used in this measure analysis as best available data.

Evaluation of Potential Best Management Practices – Residential Hot Water Distribution (Koeller, 2007).[5] This study presents an analysis of the waste of water that occurs in a typical household between the times the tap/fixture is turned ON and the desired hot water arrives at the fixture outlet. In a laboratory setting, this study quantified structural waste in terms of water in pipe (100 ft. of pipe) and determined the relationship between flow rate and structural waste.

Taitem Tech Tip – Leaking Shower Diverters (Taitem, 2011).[6] This study summarized research on leaking shower diverters in single family and multifamily homes. Analysis of survey data collected from 130 apartment and houses that represented 120 bath/shower combinations with diverters revealed that 34% of the diverters leaked more than 0.1 gallons per minute (gpm) with the average at 0.8 gpm.

Residential End Uses of Water (Aquacraft, Inc., 1999).[7] This study was designed to provide specific data on the end uses of water in single-family residences throughout the U.S. The analysis calculated a mean shower volume of 17.2 gallons from survey data from 5,000 single family households and a detailed end-use data of 1,200 single family households.

Sempra Energy Utilities (SEU) Survey (ASW, 2009).[8] The analysis of data from various residential water measurements and a household questionnaire representing 249 households revealed the mean number of showerheads in a single-family household is 2.01 and the pre-existing showerheads flow rate is 2.25 gpm.

The End Use of Hot Water in Single Family Homes from Flow Trace Analysis (Aquacraft, Inc., 2000).[9] Water trace data from ten single family homes in Seattle reveal a mean shower duration equal to 7.4

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[4] Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC.

[5] Koeller, J., and G. Klein. 2007. *Evaluation of Potential Best Managment Practices - Residential Hot Water Distribution.* Sacramento, Ca: California Urban Water Conservation Council.

[6] Taitem Engineering. 2011. "Leaking Shower Diverters." *Tech Tip, New York State Homes & Community Renewal.*

[7] Mayer, P. and W. DeOreo. 1999. Residential End Uses of Water 1999, Subject Area: Water Resources. Denver, CO: American Water Works Association (AWWA) Research Foundation.

[8] Sempra Energy Utilities (SEU). 2012. "SEU 2009 ASW Data REDACTED.xlsx".

[9] DeOreo, W., P. Mayer, and D. Lewis. 2000. *Seattle Home Water Conservation Study: The Impacts Of High Efficiency Plumbing Fixture Retrofits In Single-Family Homes.* Prepared for the Seattle Public Utilities and the U.S. Environmental Protection Agency. Boulder, CO: Aquacraft, Inc. Water Engineering and Management.

minutes. Another measurement study of residential end use of water by AWWA Research Foundation shows the similar data,[10] a median of 7.2 minutes and a mean shower duration of of 8.2 minutes. The shower duration of 7.4 minutes, along with other assumptions for this measure analysis, provides a realistic baseline shower water consumption that is equivalent to about 33% of the total domestic hot water consumption.

MEASURE CASE DESCRIPTION

The measure case is defined as an auto-diverting tub spout (ADTS) (5.0 gpm) with a thermostatic shut-off valve (TSV) that purges cold water through tub spout until the water raises to 95° F. The water is then diverted to the showerhead at a trickle until full flow (1.5 gpm) is activated via the pull cord.

Measure offerings, and therefore measure impacts, are defined by water heating fuel type (electric or gas) and residence type (single family, multifamily/double-wide mobile home).

Savings for installations in a double-wide mobile home residence are assumed to equal the savings derived for installation in a multifamily residence and will not have a separate energy impact profile.

BASE CASE DESCRIPTION

The base case is defined as a 5.0 gpm tub spout with either a 2.0 gpm or a 1.8 gpm showerhead combination.

New construction and normal replacement installations will utilize the code baseline from 2016 (2.0 gpm showerhead). *Accelerated replacement installations* will use code baseline from 2018 (1.8 gpm showerhead, due to the remaining useful life, RUL, of three years).

Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Auto-diverting Tub Spout (5.0 gpm) with TSV and 1.5 gpm showerhead
Existing Condition	5.0 gpm tub spout with a 2.25 gpm showerhead
Code/Standard (2016)	5.0 gpm tub spout with a 2.0 gpm showerhead
Code/Standard (2018)	5.0 gpm tub spout with a 1.8 gpm showerhead
Industry Standard Practice	n/a

CODE REQUIREMENTS

This measure is subject to the California Appliance Efficiency Regulations (Title 20),[11] which stipulates the maximum flow rate for showerheads. The low-flow showerhead maximum flow rate was originally

[10] Mayer, P. and W. DeOreo. 1999. Residential End Uses of Water 1999, Subject Area: Water Resources. Denver, CO: American Water Works Association (AWWA) Research Foundation. P. 102

[11] California Energy Commission (CEC). 2014. *2014 Appliance Efficiency Regulations.* CEC-400-2014-009-CMF. Section 1605.3.

mandated by the Energy Policy Act of 1992.[12] Title 20 initially matched the federal code and has exceeded it in subsequent updates.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2016)	Section 1605.3, Table H-5: The maximum flow rate of a showerhead shall not be greater than 2.5 gpm at 80 psi.	Units manufactured on or after January 1, 1994 and prior to July 1, 2016.
	Section 1605.3, Table H-5: The maximum flow rate of a showerhead shall not be greater than 2.0 gpm at 80 psi.	Units manufactured on or after July 1, 2016 and prior to July 1, 2018.
	Section 1605.3, Table H-5: The maximum flow rate of a showerhead shall not be greater than 1.8 gpm at 80 psi.	Units manufactured on or after July 1, 2018.
Federal Standards - Energy Policy Act of 1992	Requires that showerheads must use no more than 2.5 gpm at 80 psi.	Effective January 1, 1994

NORMALIZING UNIT

Each.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal replacement	DnDeemDI	Res
Normal replacement	UpDeemed	Res
Normal replacement	DnDeemed	Res
New construction	DnDeemDI	Res

[12] H.R.776 – 102nd Congress. Energy Policy Act of 1992. Pub. L. 102-486. Stat. 2776.

Measure Application Type	Delivery Type	Sector
New construction	UpDeemed	Res
New construction	DnDeemed	Res
Accelerated replacement	DnDeemDI	Res
Accelerated replacement	UpDeemed	Res
Accelerated replacement	DnDeemed	Res

Eligible Products

To ensure eligibility, the make and model number must be included with a copy of the purchase receipt.

The product must be certified by International Association of Plumbing and Mechanical Officials (IAPMO).

To ensure eligibility, the make and model number must be included with a copy of the purchase receipt.

Eligible Building Types and Vintages

This measure is applicable in single-family, multifamily, and double-wide mobile homes with a tub/shower combination.

Eligible Climate Zones

This measure is applicable in any California climate zone.

PROGRAM EXCLUSIONS

The measure cannot be applied where tankless water heaters are used.

Instantaneous tankless water heaters may have different effect on savings with thermostatic shut-off valves.

This measure is not compatible with showers with a wall-mounted diverter.

DATA COLLECTION REQUIREMENTS

There is currently no single study which is recognized as a statewide acceptable report on the use of hot water in tub/shower combinations for single family and multifamily/double-wide mobile home residences. The studies summarized in the Technology Summary are the best available data at the time of this analysis. Further research is needed both in the area of hot water usage in tub/shower combinations (including warm-up practices) and current pre-existing conditions for both tub spout and showerhead. Code changes for showerhead flow rates and the persistent drought throughout California underscore the need for research to update showerhead flow rates and other determinant factors of water and energy usage.

USE CATEGORY

Service & Domestic Hot Water

ELECTRIC SAVINGS (KWH)

As shown below, the electric UES is derived from the gas UES, the ratio of the recovery efficiency of a gas water heater to that an electric water heater, and a therm-to-kWh conversion factor.

$$UES_{kWh,showerhead} = UES_{therms,showerhead} \times \frac{EFF_{gas}}{EFF_{elec}} \times \frac{100{,}000\ BTU}{therms} \times \frac{kWh}{3{,}413\ BTU}$$

UES_{kWh} =	*Annual electric unit energy savings of showerhead (kWh/yr)*
UES_{therms} =	*Annual gas unit energy savings of showerhead (therms/yr)*
EFF_{gas} =	*Min. water heater efficiency (recovery efficiency), gas*
EFF_{elec} =	*Min. water heater efficiency (recovery efficiency), electric*

Refer to the Gas Savings section for the derivation of the gas UES. All other inputs used for this calculation are specified below.

Electric UES Inputs

Energy Savings Inputs / Constants	Units	Value	Source
Gas Unit Energy Savings	Therms	Varies by CZ	See Gas Savings section.
Gas Water Heater Min. Efficiency (recovery efficiency)	unitless	0.77	Southern California Gas Company (SCG). 2010. "Gas Fired Storage Water Heater Extract from CEC Appliance Data 07.07.2010.xlsx." California Public Utilities Commission (CPUC), Energy Division. 2010. *Non-DEER Measure Review Template: PGECODHW113 – Low Flow Showerhead and Thermostatic Shower Restriction Valve.* April 27.
Electric Water Heater Min. Efficiency (recovery efficiency)	unitless	0.98	California Energy Commission (CEC). 2014. *2014 Appliance Efficiency Regulations.* CEC-400-2014-009-CMF. Section 1604.

PEAK ELECTRIC DEMAND REDUCTION (KW)

Peak electrical demand reduction is calculated as a function of the electric UES, a peak period usage factor, and the operating hours per year. The peak period usage factor (PPUF) – similar in concept to a coincident demand factor (CDF) – reflects the percent of hot water usage during the designated peak demand period.

$$kW_{reduction} = \frac{UES_{kWh} \times PPUF}{(DAYS \times PEAKHRS)}$$

UES_{kWh} =	*Annual electric unit energy savings (kWh/yr)*
$PPUF$ =	*Peak period usage factor*
$DAYS$ =	*Operating days per year (days)*
$PEAKHRS$ =	*Peak hours per day*

Peak Demand Reduction Parameters

Parameter	Value	Source
Peak Period Usage Factor (PPUF)	0.37	Southern California Edison (SCE). 2019. "Water Heater - Electric Peak Usage Factor adjustment to new TOU.xlsx"
Operating days per year	365	Professional judgement
Peak hours per day	5	California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Op 1.

GAS SAVINGS (THERMS)

The estimation of gas unit energy savings (UES) The UES is a function of the water usage and water savings, which accounts for structural waste, behavioral waste, tub spout leakage, and reduced water flow during a shower.

Establish baseline water usage. Baseline water usage is a function of structural waste, behavioral waste, shower time and water usage, and tub spout leakage rate.

1. *Structural waste*, or the time it takes for hot takes to reach the water fixture, is the percentage of showerhead warm up compared to tub spout warm up
2. *Behavioral waste*, or the time it takes for the user to enter shower less structural waste time, is the percentage of tub spout warm up while the user is "multi-tasking"
3. *Tub spout leakage* percentage and rate
4. *Shower time and shower water usage* are represented by: showerhead and tub spout flow rates, shower mixed daily water usage (varies by single family and multifamily/double-wide mobile home), and the number of showers per day (varies by single family and multifamily/double-wide mobile home)

Calculate water savings. Water savings is a function of forced tub spout warm up, reduction of behavioral waste, reduction of tub spout leakage, and reduction of showerhead flow rate.

Calculate Energy Savings. The gas UES is calculated by converting water savings to therm savings. The resultant UES values are consistent with findings in "Auto-Diverting Tub Spout System with ShowerStart TSV".[13]

Establish Baseline Water Usage

Baseline water usage is a function of: structural usage, behavioral usage, and shower usage. See Inputs and Assumptions below for details and sources.

[13] Sherman, T. (Evolve Technologies). 2015. "Calculating Savings for Auto-Diverting Tub Spout System with ShowerStart TSV." May 18.

Structural Usage

Input	Calculation	Calculated Value
Structural Waste	*StWt = BWt / BWp – BWt*	33 sec/Warm-up
Tub Spout Leak during Structural Waste Time	*TslStw = StWt / C1 * TslR*	0.44 gal/Warm-up
Shower Structure Waste	*ShStw= StWt / C1 * ShFr*	1.10 gal/Warm-up
Amount of Water in Pipe	*Wtp= ShStw / SP*	0.85 gal
Tub Structure Waste	*TsStw = WtP * TsWuPWt*	0.89 gal/Warm-up
Weighted Structural Waste w/ Tub Spout Leak Weighted	*WStwTslW = (ShStw + TslStw * TslP) * ShWu + TsStw * TsWu*	1.11 gal/warm-up

Behavioral Usage

Input	Calculation	Calculated Value
Tub Spout Behavioral Waste	*TsBwP = TMWu * TsWu*	23%
Tub Spout Leak during Behavioral Waste	*TslBw = BWt / C1 * TslR*	0.627 gal/Warm-up
Shower Behavioral Waste =	*ShBw = BWt / C1 * ShFr*	1.57 gal/Warm-up
Tub Behavioral Waste	*TsBw = BWt /* C_1 ** TSFr*	3.92 gal/Warm-up
Weighted Behavioral Waste w/ Tub Spout Leak Weighted	*WBwTslW = (ShBw + TslBw * TslP) * ShWu + TsBw * Bwp*	1.98 gal/Warm-up

Shower Usage

Input	Calculation	Calculated Value
Actual Shower Time	*Sht - (StWt + BWt) /* C_1	6.07 min
Actual Shower Time Water Usage W/ Tub Spout Leak Weighted	*Asht * (ShFr + TslR * TslP)*	13.78 gal/shower

Calculate Water Savings

Water savings result from the forced tub spout warm-up, elimination of of behavioral waste, reduction of tub spout leak, and reduction in the showerhead flow rate. The calculation for each of these key drivers of water savings are presented below. See Inputs and Assumptions below for details and sources.

Forced Tub Spout Warm-up

Input	Calculation	Calculated Value
Tub Structure Waste	*WtP * TsWuPWt*	0.89 gal/warm-up
Weighted Structural Waste w/ Tub Spout Leak Weighted	*(ShStw + TslStw * TslP) * ShWu + TsStw * TsWu*	1.11 gal/warm-up
Structural Water Savings	*WStwTslW - TsStw*	0.21 gal/warm-up

Removal of Behavioral Waste

Input	Calculation	Calculated Value
Weighted Behavioral Waste w/ Tub Spout Leak Weighted	(ShBw + TslBw * TslP) * ShWu + TsBw * Bwp	1.98 gal/warm-up
Behavioral Water Savings	WBwTslW – 0	1.98 gal/warm-up

Removal of Tub Spout Leak and Reduction in Showerhead Flow Rate

A 2.0 gpm Showerhead flowrate is used in the baseline (AShtWuTslW) formula and 1.5 gpm in the proposed case (AShtWuP) formula.

Input	Calculation	Calculated Value
Actual Shower Time Water Usage W/ Tub Spout Leak Weighted	Asht * (ShFr + TslR * TslP)	13.78 gal/shower
Actual Shower Time Water Usage W/out Tub Spout Leak	Asht * ShFr	9.10 gal/shower
Shower Time Water Savings	AShtWuTslW - AShtWuP	4.68 gal/shower

Total Shower Water Savings

Input	Calculation	Calculated Value
Total Shower Water Savings w/ Tub Spout Leak Weighted	StWtrS + BWtrS + ShtWtrS	6.87 gal/shower

Annual Single-Family and Multifamily/Double-wide Mobile Home Water Savings

Input	Calculation	Calculated Value
Single Family Mixed Daily Water Usage		24.90 gal/day
SF Showers per Day, per showerhead	*SFMDW / (TShWuPr * SFSh)*	0.72 showers/day
SF Water Savings	*TShWtrS * SFSpD * 365 days/year*	1,806.95 gal/year
Multifamily/Double-wide Mobile Home Mixed Daily Water Usage		20.75 gal/day
MF Showers per Day, per showerhead	*MFMDW / (TShWuPr * MFSh)*	0.80 showers/day
MF Water Savings	*TShWtrS * MFSpD * 365 days/year*	2,017.62 gal/year

Calculate Gas Energy Savings

The gas UES is equal to the energy required to raise the volume of water saved from ground water temperature to the water temperature at the showerhead. The values and equation used to make the conversion is shown below.

$$UES_{therms} = \left[\frac{(W_{savings} * \rho * C_p * (T_{mixed} - T_{supply}))}{RE_{Gas} * C_{volume}}\right] * \left[\frac{1\ Therm}{100{,}000\ BTU}\right]$$

$W_{savings} = Water\ savings$
$\rho = Water\ density\ at\ 60\ °F$
$C_p = Water\ specific\ heat\ at\ 60\ °F$
$T_{mixed} = Mixed\ water\ temperature\ at\ showerhead$

T_{ground} = *Supply water (groundwater) temperature*
RE_{Gas} = *Recovery efficiency*
C_{volume} = *Gallons to cubic feet Conversion*

Savings for installations in a double-wide mobile home residence are assumed to equal the savings derived for installation in a multifamily residence and will not have a separate energy impact profile.

Inputs and Assumptions

Water Usage and Water Savings Inputs

The table below specifies the baseline assumptions and all inputs for the water usage and water savings calculations; brief explanations of each follow this table.

Water Usage and Water Savings Inputs

Variable	Parameter	Value	Source
ShFr	Showerhead flow rate (gpm)	2.0	California Energy Commission (CEC). 2017. *2016 Appliance Efficiency Regulations*. CEC-400-2017-002. Section 1605.3
Tfr	Tub spout flow rate (gpm)	5.0	
SFMDW	Mixed daily water usage, showers – single family (gpd)	28.01	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.
MFMDW	Mixed daily water usage, showers – multifamily (gpd)	23.34	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.
ShWu	% Showerhead warm-up	60%	Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC. p.8
TsWu	% Tub spout warm-up	40%	Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC. p.5
SP	Showerhead warm-up pipe water purged	130%	Koeller, J., and G. Klein. 2007. *Evaluation of Potential Best Managment Practices - Residential Hot Water Distribution.* Sacramento, Ca: California Urban Water Conservation Council. P.44-45.
TsWuPWt	Tub spout warm-up pipe water purged	106%	Koeller, J., and G. Klein. 2007. *Evaluation of Potential Best Managment Practices - Residential Hot Water Distribution.* Sacramento, Ca: California Urban Water Conservation Council. P.44-45.
BWt	Behavioral waste time (sec/shower))	47	Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC. p11

Variable	Parameter	Value	Source
BWp	Behavioral waste, % of warm up waste	59%	Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC. p11
TMWu	Tub multi-tasking warm up (%)	58%	Sherman, T. 2014. *Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based On Data From Lawrence Berkeley National Labs.* Scottsdale: AZ. Evolve Technologies, LLC. p5
TsIP	Tub spout leakage (%)	34%	Taitem Engineering. 2011. "Leaking Shower Diverters." *Tech Tip, New York State Homes & Community Renewal.*
TsIR	Tub spout leak rate (gpm)	0.8	Taitem Engineering. 2011. "Leaking Shower Diverters." *Tech Tip, New York State Homes & Community Renewal.*
TShWuPr	Total shower water usage, pre-existing (gal/shower)	17.2	Mayer, P. D. 1999. *Residential End Uses of Water.* Denver, Co: AWWA Research Foundation and American Water Works Association. P. 102
SFSh	Number of showerheads per household – single family	2.01	Sempra Energy Utilities (SEU). 2012. "SEU 2009 ASW Data REDACTED.xlsx".
MFSh	Number of showerheads per household – multifamily	1.50	U.S. Census. 2014. *Bathrooms Customer.* 2015.
Sht	Shower time (min)	7.4	DeOreo, W., P. Mayer, and D. Lewis. 2000. *Seattle Home Water Conservation Study: The Impacts Of High Efficiency Plumbing Fixture Retrofits In Single-Family Homes.* Prepared for the Seattle Public Utilities and the U.S. Environmental Protection Agency. Boulder, CO: Aquacraft, Inc. Water Engineering and Management.

Showerhead Flow Rate. With the flow rate of 2.25 gpm for the existing condition[14] and the code update to 2.00 gpm, it was decided to use code as the current code baseline and 1.80 gpm for *accelerated replacement* code baseline due to the three-year remaining useful life (RUL) period.

Tub Spout Flow Rates. With limited studies on tub spout flow rates a market assessment shows significant spouts available above 5 gpm. Since 5 gpm is the flow rate of the ADTS, it was chosen as the baseline flow rate so no savings would be derived from the tub spout flow rate alone.

Mixed Daily Water for Showers. The 2013-2014 domestic hot water fixture disposition issued by the California Public Utilities Commission[15] established the mixed daily water for shower usage with a 2.25 gpm showerhead. The ratio of the values 2.25 gpm over 2.0 gpm was used to calculate the baseline mixed daily water usage. Mixed daily water usage is used to calculate the number of showers take per day.

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[14] Sempra Energy Utilities (SEU). 2012. "SEU 2009 ASW Data REDACTED.xlsx"

[15] California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.

California Public Utilities Commission (CPUC), Energy Division. 2013. "2013-2014_DHWFixtureMeasures_Disposition-1March2013.xls." February 22.

Structural Waste. In a tub/shower combination the user has the option to purge the cold water via the showerhead or the tub spout. Tub spout warm-ups are found to save both time and energy when compared to showerhead warm-ups due to the faster flow rate. Tub spout warm-ups are found to occur during 40% of the time in tub/shower combos. Structural waste time is calculated by subtracting the behavioral waste time from the total warm-up waste time.

Behavioral Waste. Behavior waste occurs between the time when the water reaches desired temperature until the user steps in the shower. Because of the faster warm-up with a tub spout, it is more likely that the user will sit near the tub to wait for hot water before entering the shower. This does not always occur and 58% of users initiating tub spout warm-ups were found to multitask during warm-up. Behavioral waste time varies; thus, a conservative value was adopted for this analysis.

Weighted Average Showerheads per Household. The survey data from the Sempra Energy Utilities (SEU) territories study was averaged to be 2.01 showerheads per single-family household. Data from the U.S. Census Bureau was used to calculate the weighted average showerheads per household for the multi-family residences, using the number of bathrooms per household for new construction of multifamily units between the years 1978-2014.

Shower Duration. Water trace data from ten single family homes in Seattle revealed an average shower duration of 7.4 minutes. Another measurement study of residential end use of water by the AWWA Research Foundation estimated a similar result, a median of 7.2 minutes and a mean of 8.2 minutes. Shower duration of 7.4 minutes, along with other assumptions, results in more realistic baseline shower water consumption that is equivalent to about 33% of the total domestic hot water consumption.

Gas UES Inputs

The inputs and assumptions to derive the gas UES are specified and described below.

Gas UES Inputs

Parameter	Value	Source
Specific Heat Capacity of Water (Btu/lb/°F)	1	Fixed constant
Water Weight (lb/gal)	8.34	Fixed constant
Gallons to cubic feet conversion (gal/ft^3)	7.5	Fixed constant
Water density (lbm/ft$_3$)	62.37	Fixed constant
Average Make-up (Groundwater) Water Temperature (°F)	Varies by climate zone	See below.
Mixed Water Temperature @ Faucet (°F)	106	Sempra Energy Utilities (SEU). 2012. "SEU 2009 ASW Data REDACTED.xlsx".
Gas Water Heater Min. Efficiency (recovery efficiency)	0.77	Southern California Gas Company (SCG). 2010. "Gas Fired Storage Water Heater Extract from CEC Appliance Data 07.07.2010.xlsx." California Public Utilities Commission (CPUC), Energy Division. 2010. *Non-DEER Measure Review Template: PGECODHW113 – Low Flow Showerhead and Thermstatic Shower Restriction Valve.* April 27.

Mixed Water Temperature. For low-flow showerheads, the outlet water heater temperature accounts for tempering of the hot water with cold water to establish full shower flow. Hot water does not comprise the entire shower flow, so evaluating a smaller water heater temperature rise limits the water heater energy attributable to entire shower flow.

Supply (Groundwater) Water Temperature. The water temperature entering the water heater varies by climate zone; average groundwater temperatures by climate zone are provided below.

Make-up (Groundwater) Water Temperatures by Climate Zone

Climate Zone	Make-up (Groundwater) Temperature (°F)	Source
CZ 1	51.4	Reeves, P. (Consultant to California Public Utilities Commission, Energy Division). 2013. "Comparison-of-Ground-Temperatures-v2_byPaulReeves.xlsx."
CZ 2	57.3	
CZ 3	57.1	
CZ 4	59.5	
CZ 5	55.8	
CZ 6	61.8	
CZ 7	62.6	
CZ 8	63.7	
CZ 9	63.8	
CZ 10	64.2	
CZ 11	63.2	
CZ 12	60.9	
CZ 13	64.1	
CZ 14	62.7	
CZ 15	75.5	
CZ 16	51.8	

Recovery Efficiency: To convert the water heating load to gas energy use at the water heater, the recovery efficiency (RE) is used. Recovery efficiency is a measure of how efficiently the heat from the energy source is transferred to the water (the ratio of energy output used to heat the water divided by energy input). A weighted RE value was derived from the natural-gas fired, storage-type water heaters extracted from the California Energy Commission (CEC) database of certified equipment (without limit to the listed equipment energy factor, EF). RE was subsequently stipulated by the Energy Division of the CPUC.[16]

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would

[16] California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.

have remained in service and operational had the program intervention not caused the replacement or alteration.

The EUL and RUL specified below is the estimated lifetime of a low-flow showerhead because the tub spout and showerhead technologies are subjected to similar conditions and are assumed to have approximately the same useful life.

Effective Useful Life and Remaining Useful Life

Type	Gas	Electric	Source
Single Baseline for Normal Replacement			California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
EUL	10.00	10.00	
RUL	n/a	n/a	
Dual Baseline for Accelerated Replacement			California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.
RUL =1/3 EUL	3.33	3.33	
EUL - RUL	6.67	6.67	

BASE CASE MATERIAL COST ($/UNIT)

Base case cost data was obtained in March and April of 2016 from online retailers of showerheads and tub spouts (Home Depot and Lowes).[17] (Note that the cost data for low flow showerheads in the Database of Energy Efficient Resources, DEER, originated in DEER 2008 and does not provide the showerhead flow rate.)

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material cost data was obtained in March and April of 2016 from online retailers of showerheads and tub spouts (Home Depot and Lowes). [18]

BASE CASE LABOR COST ($/UNIT)

The base case installation labor cost was obtained from the 2010-2012 Ex Ante Measure Cost Update Study conducted by Itron, Inc.[19]

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[17] Southern California Gas Company (SCG). 2016. "Tub Spout and Showerhead Cost Data 2016.xlsx"

[18] Southern California Gas Company (SCG). 2016. "Tub Spout and Showerhead Cost Data 2016.xlsx".

[19] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

MEASURE CASE LABOR COST ($/UNIT)

The measure case labor cost data was obtained in March and April of 2016 from online retailers of showerheads and tub spouts (Home Depot and Lowes). [20]

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The residential default NTG ratio is based upon the average of all NTG ratios for all evaluated 2006 – 2008 residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. This sector average NTG ("default NTG") is applicable to all energy efficiency measures that have been offered through residential programs for more than two years and for which impact evaluation results are not available. Additionally, a NTG ratio is specified for direct installation delivery if a customer meet the qualifications of hard-to-reach (HTR) customer established by the California Public Utilities Commission (CPUC).

Net-to-Gross Ratios

Parameter	Value	Source
NTG – residential default	0.55	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Table 15-3 Page 15-4.
NTG – direct install for hard-to-reach	0.85	

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. The GSIA rate specified this measure is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Saving Installation Adjustment Rate

Parameter	GSIA	Source
GSIA - Default	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

The non-energy impacts for this measure have not been quantified.

[20] Southern California Gas Company (SCG). 2016. "Tub Spout and Showerhead Cost Data 2016.xlsx".

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER 2016
Reason for Deviation from DEER	DEER does not contain this type of measure.
DEER Measure IDs Used	n/a
NTG	Source: DEER. The NTG of 0.55 is associated with NTG ID: *Res-Default>2.* The NTG of 0.85 is associated with NTG ID*: Res-Default-HTR-di*
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER. The value of 10 years is associated with EUL ID: *WtrHt-WH-Shrhd.*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	06/30/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: SWWH001v00, Revision 0 (April 25, 2016 Consensus reached among Cal TF members.
	01/31/2019	Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01
	11/01/2019	Ayad Al-Shaikh Cal TF Staff	Corrected calculation error in conversion from Gas to Electric savings. Removed text references to NTG Adjustment Factor.
	04/02/2021	Soe K Hla PG&E	Adopted all measures for PG&E Fixed spelling error DnDeemDI, incorrect MeasCostID and StdCostID, incorrect ElecImpactProfile ID and incorrect NTG ID for SCE Implementation in EAD