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Potential Water and Energy Savings from Showerheads

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Disclaimer

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Potential Water and Energy Savings from Showerheads

1.0 SUMMARY

To prioritize potential water and energy saving scenarios regarding showerheads, six scenarios were analyzed for their potential water and energy savings and the associated dollar savings to the consumer. Because of the uncertainties in parameters affecting the savings, ranges were used for inputs to the calculations as well as reported in the outputs. The scenarios and rankings are listed in Table 1 below. The saving are reported as percentages of baseline showerhead use. The minimum and maximum values show the uncertainty of the possible national savings and are not intended to show variability of saving at the individual household level.

Table 1: Ranking of Showerhead Scenarios [(1)]

Rank	Scenario	Mean Percent savings of water[(1)]	Range Minimum	Range Maximum
1	Change all showerheads that meet standard to below standard (from 2.5 to 2.0 gpm)	16.4%	13.0%	20.5%
2	Change all showerheads that exceed standard to meet standard	16.3%	4.8%	33.8%
3	Reduce average showering time by 1 minute	12.2%	11.9%	12.5%
4	Counteract the trend toward using multiple showerheads, body spas, etc.	4.8%	0.3%	17.7%
5	Reduce number of showerheads tampered with (modified to increase the flow)	3.6%	0.1%	11.2%
6	Reduce tub spout leakage	0.1%	0.0%	0.5%

[(1)] Percent of baseline showerhead water use

2.0 OBJECTIVE

This report presents results from a preliminary assessment of potential water savings from showerheads, in order to establish research priorities and to inform policies that encourage market transformation.

3.0 INTRODUCTION

Reducing the water and associated energy consumption of residential and commercial showerheads has potential even though a maximum water flow is already stipulated in Federal regulations[a] (see Appendix A). The Federal efficiency standard requires

[a] U.S. Dept. of Energy, Final Rule: "Energy Conservation Programs for Consumer Products: Test Procedures and Certification and Enforcement Requirements for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances," *Federal Register* (63 FR 13308), March 18, 1998. http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/plmrul.pdf

showerheads to allow a flow of no more than 2.5 gallons per minute. Anecdotal evidence suggests several opportunities for savings:

- In practice, it appears as if not all showerheads being sold are in compliance with the Federal standard.
- Trends in shower design are headed toward having multiple showerheads.
- Showerheads may be available that perform well and use less than the maximum allowed flow rate.
- After purchasing showerheads, some consumers tamper with them to increase water flow.
- Tub spouts waste water by leaking when water is diverted to the showerhead.

Water utilities and other stakeholders have begun testing and conducting research to reduce showerhead water use and coincident energy consumption. The primary focus of this report is to rank potential approaches to reducing showerhead water consumption in order to establish research priorities and to prioritize showerhead water conservation programs. The amount of water used by showers nationwide could be reduced in several ways.

- Results of testing showerheads can provide an enforcement function, so showerheads that exceed the federal standard for water flow (2.5 gallons per minute, gpm) are identified and removed from the market.
- Showerheads that use even less than 2.5 gpm and provide a good shower experience can be identified and promoted.
- Information about which showerheads consumers are most likely to find satisfactory will encourage them to switch to effective low-flow[a] showerheads and discourage them from installing non-compliant showerheads. Identifying low-flow showerheads that provide an adequate shower also may encourage consumers to avoid purchasing multi-head shower fixtures.
- Research into ways to encourage consumers to turn off water while lathering also could save water.
- Perceived or real safety considerations may prevent utilities from promoting very low flow showerheads and therefore, these issues must be researched.

This report quantifies the national water and energy savings of six scenarios below.

1. Replace all showerheads that meet standard to operate below standard (from 2.5 gpm to 2.0 gpm).
2. Replace all showerheads that exceed standard to meet standard.
3. Reduce average showering time by 1 minute.
4. Counteract the trend toward using multiple and high flow showerheads, body spas, etc.
5. Reduce number of showerheads tampered with (modified to increase flow).
6. Reduce leakage from tub spouts when a diverter sends water to the showerhead.

The potential water and energy savings are quantified for each scenario based on 100% participation rates.

[a] Low-flow means 2.5 gpm or less; at least meeting the maximum allowed flow regulations

4.0 ANALYSIS

This section describes the basis for the analysis of the six showerhead scenarios identified for study.

4.1 Data and Assumptions

Data and assumptions are summarized in Table 2, below.

Inputs

Many of the variables that determine showerhead water use in the field are not known with certainty. In some instances data are not available, in others survey or measurement data may not be nationally representative or may be many years old. Showerhead water use is estimated under various scenarios using a range of input parameters. These inputs are characterized as probability distributions, with estimates of the most likely value and the estimated minimum and maximum values. Many of the inputs were entered into a spreadsheet as a probability distribution, with the distribution being triangular or uniform. The most likely value is given maximum probability in the triangular distributions. Minimum and maximum values bound the range. The mean is the calculated mean value of the distribution. If the minimum and maximum are the same distance from the most likely value, than the mean is the same as the most likely value. Otherwise the distribution is skewed. These input data are then used with the applicable equations to generate a probability distribution for an output value. Since this report is interested in national aggregate effect on water use, only the uncertainty of the *average* values is used as an input uncertainty and not the entire distribution due to the variability of individual shower events. Table 3 shows the sources of the input parameters provided in Table 2. These input parameters are discussed in greater detail in section 4.2.

Outputs

Using a program called *Crystal Ball*©, an *Excel* © spreadsheet add-in, calculations generate a frequency distribution of outputs. Data on the mean, minimum and maximum output values are also generated. Appendix E shows the probability distributions of the percent water savings for each scenario.

The parameters in Table 2 are annotated to show in which scenario the parameter is used.

- Scenario 1 [S1]: Change all showerheads that meet standard to below standard
- Scenario 2 [S2]: Change all showerheads that exceed standard to meet standard
- Scenario 3 [S3]: Reduce average showering time by 1 minute
- Scenario 4 [S4]: Counteract the trend toward using multiple showerheads, body spas, etc.
- Scenario 5 [S5]: Reduce number of showerheads tampered with
- Scenario 6 [S5]: Reduce tub spout leakage

Table 2: Data and Assumptions

Parameter	Value				
	Mean	Most likely	Minimum	Maximum	Type of Distribution
General Inputs					
U.S. population (million)	290	n/a	n/a	n/a	n/a
Persons per household	2.59	n/a	n/a	n/a	n/a
Showers per day	0.7	0.7	0.65	0.75	Uniform
Average shower duration (minutes)	8.2	8.2	8	8.4	Triangular
Throttling factor (1) **[S1]**	0.9	0.9	0.8	1	Uniform
Flow Rates of Showerheads (gpm)					
Flow of average showerhead (1999 baseline) **[S2][S3][S4][S5]**	2.2 gpm	2.2	2.0	2.4	Triangular
Flow (rated standard @ 80 psig)**[S1]**	2.5 gpm	n/a	n/a	n/a	n/a
Flow of above standard (high flow) showerhead **[S2]**	4.0	4	3	5	Uniform
Flow of old (or tampered with) showerhead **[S5]**	3.5	3.5	3	4	Uniform
Flow below standard (low rated flow) showerhead **[S1]**	2.0	n/a	n/a	n/a	n/a
Flow of multiple-head showerheads **[S4]**	5.5	4	2.5	10	Triangular
Percentages of Different Showerheads					
Percent with flow rates that exceed the standard **[S2]**	20%	20%	15%	25%	Triangular
Percent tampered with **[S6]**	6%	6%	0%	12%	Triangular
Percent of households having low-flow showerheads (less than 2.5 gpm) **[S1]**	80%	80%	75%	85%	Triangular
Percent multiple-head showerheads **[S4]**	4.3%	4%	3%	6%	Triangular
% of time multiple-head SH is used **[S4]**	75%	75%	50%	100%	Uniform
Tub Spout Data					
Tub spout leakage - old (gpm)	0.2	0.2	0.1	0.3	Triangular
Tub spout leakage - new (gpm)	0.03	0.03	0.01	0.05	Triangular
Percent of all showers having a tub spout	62%	62%	60%	64%	Triangular
Percent with tub spout not in compliance with CEC	5%	5%	0%	10%	Uniform
Percent time shower is used with tub spout	50%	50%	25%	75%	Triangular
Energy and Water Prices					
Electricity Rate (per kWh)	$.0906				
Natural Gas Rate (per Therm)	$ 1.092				
Water & Wastewater Rate (per 1000 gallons)	$3.19				
Energy use per gallon of shower water					
Cold water inlet temperature	60ºF				
Shower temperature	105ºF				
Electric water heater recovery efficiency	98%				
Gas water heater recovery efficiency	75%				
Percent of water heaters using electricity	42%				
Percent of water heaters using gas	58%				

(1) The throttling factor adjusts the rated flow to account for pressures at less than 80 psig, and for limiting the flow by throttling back (closing) the control valve to the shower. This may be done to adjust the water temperature.

Table 3: Input Parameters

Parameter	Comment	Source
General Inputs		
U.S. population (million)	Census 2000 (estimate for 2002)	U.S. Census[1]
Persons per household	Census year 2000	U.S. Census[2]
Showers per day per person	Combined baths and showers	REUW[3], p. xxvii
Average shower duration (minutes)	From metered data	REUW, p. 99
Throttling factor	Estimate of author	
Flow Rates of Showerheads		
Flow rate of average showerhead (1999 baseline)	Baseline (pre-retrofit) value from Seattle study in 2000	Seattle[4]
Flow rate (current standard @ 80 psig)	Current federal regulation -maximum flow at 80 psig	DOE[5]
Flow rate of above standard (high-flow) showerhead		
Flow rate of old (or tampered with) showerhead		
Flow rate below standard showerhead	A "what if" scenario	
Flow of multiple-head showerheads	PMI sponsored a survey of its members – Jan. 2006	W&W Services
Percentages of Different Showerheads		
Percent with flow rates that exceed the standard	1999 study showed 24.4% showered exclusively above the low flow range	REUW, p. 134
Percent tampered with	Survey for a retail coupon program showed 6% low-flow showerheads removed or not used	PG&E, p. I-12[6]
Percent of households having low-flow showerheads	Based on a study that showed 24.4% showered exclusively above the low flow range	REUW, p. 134
Percent multiple-head showerheads	Survey sponsored by PMI	W&W Services
Tub Spout Data		
Tub spout leakage (old) (gpm)	Based on CEC regulations, March 2001 and March 2003. See text.	CEC[7]
Tub spout leakage (new) (gpm)		
Percent of all showers having a tub spout	Showers were part of a combined shower-bathtub fixture	REUW, p. 99
Percent with tub spout not in compliance	Estimate	
Percent time shower is used with tub spout	Estimate	
Energy and Water Prices		
Electricity Rate (per kWh)	Representative average unit costs of residential energy (2005)	DOE[8]
Natural Gas Rate (per Therm)	Representative average unit costs of residential energy (2005)	DOE
Water & Wastewater Rate (per 1000 gallons) (Average marginal rate in1998 adjusted to 2004)	Based on marginal rates using 1998 Raftelis data & updated to year 2004	DOE, CW TSD 2000 Appendix F
Energy use per gallon of shower water		
Cold water inlet temperature	Estimate	
Shower temperature	Estimate	
Electric water heater recovery efficiency	Assumptions per DOE test procedures	
Gas water heater recovery efficiency		
Percent of water heaters using electricity	Assuming all water heaters are either gas or electric	TSD DOE rulemaking[9]
Percent of water heaters using gas		

4.2 Discussion of Input Parameters and Assumptions

Population
The same value is used in all scenarios.

Persons per Household
The value of 2.59 persons per household includes all age groups.

Showers per Day
The *REUW* study[10] gives an average of 0.75 combined showers & baths per day per capita,, with a range from 0.63 to 0.90. The study is based on data from 12 locations in the United States.

It is important to note that these values are for showers and baths. We used an estimate of 0.7 showers per day because we do not want to include baths. (It may be possible to disaggregate the showers and baths from raw data from the REUW study.)

Average Shower Duration
This analysis uses the result from the *REUW* study in which measured data provided an average shower length of 8.2 minutes and 11.6 gallons per capita per day. (Since on average the population takes less than one shower a day, the flow rate should not be computed from these two values.) The *REUW* study provides a distribution of shower duration. However, since this report is interested in national aggregate effect on water use, only the average value is used, with an estimate of the uncertainty of this average.

The length of shower is probably somewhat correlated with the flow rate and performance of the showerhead. In addition, new showers that provide a spa-like relaxation benefit may have different usage than showers taken only for cleanliness purposes.

Studies have reached conflicting conclusions about whether shower duration is affected by switching to a low-flow showerhead. Three recent AWWA end-use studies *(Seattle, EBMUD, Tampa*)[a] indicated that the duration of showers was similar with and without low-flow showerheads.

Throttling Factor
The throttling factor adjusts the rated flow to account for pressures at less than 80 psig, and for limiting the flow by throttling back (closing) the control valve to the shower, which may be done to adjust the water temperature. In addition, partial clogging may have as much or more impact on measured flow rate in the field. Partial clogging may be from debris in the pipe or from calcium deposits in areas with hard water.

A 2.5 gpm rated showerhead may have actual flows of 2 to 2.5 gpm in the field depending on factors including whether its design is pressure compensating. Pressure compensating heads have become much more common over the last few years. This type

[a] http://www.cuwcc.org/products_tech.lasso

of showerhead is more likely to flow at or close to the rated flow regardless of pressure or throttling issues. If a showerhead is not pressure compensating, then 2.5 gpm at 80 psig is theoretically equivalent to 2.2 gpm at 60 psig. The estimated range of throttling factors used in this report is 0.8 to 1.0 with an average of 0.9. The 0.8 value is derived from dividing 2gpm by 2.5gpm. The throttling factor is only used in this study for scenarios 1 and 2 where the inputs are expressed as *rated* flow rates instead of *actual* field measured flow rates.

Vickers references a 1984 report by Brown & Caldwell that shows actual flow rates often differ from rated flow rates by about two-thirds, suggesting a larger throttling factor. These study also showed that the throttling factor varied with the flow rate. However, the report cited by Vickers is from 1984, so it would include older higher flow showerheads.

Flow Rate of Average Showerhead (baseline)
The baseline value of 2.2 gpm is based on actual flow rates from *REUW* . This gives the baseline in 1999. The *Seattle* study in 2000 also showed a 2.2 gpm average flow based on pre-retrofit measurements.

Flow Rate of Current standard showerheads at 80 psig.
The rated maximum flow is 2.5 gpm at 80 psig. Throttling factors need to be used when analyzing scenarios based on a minimum regulated flow rate at 80 psig.

Flow Rate of Above Standard (high-flow) Showerheads
The estimate of 3 to 5 gpm (most likely 4 gpm) is based on flow rates of old showerheads and some advertised on the internet to provide flow above the required maximum.

Flow Rate of Old (or Tampered With) Showerheads
The estimate of 3 to 4 gpm assumes the flow would be 20-60% greater than that allowed by the current regulations.

Flow Rate of below standard (low-flow) showerheads
The maximum flow rate is assumed to be 2.0 gpm.

Flow Rate of Multiple-Head and High Flow Showerheads
The flow rate for these types of showerheads may be as low as 2.5 gpm, or as high as 10 gpm, based on recent tests by the CEC (confirming web site advertising flow rates as high as 10 gpm). We assumed that the most likely flow rate for this type of showerhead would be 4 gpm. The heavily skewed triangular distribution results in a mean estimate of 5.5 gpm.

Percent of Showerheads that exceed the current standard flow rate
The *REUW* study found that 24% of showerheads had flow rates greater than the current maximum allowed by legislation. The Federal legislation prohibiting the manufacture of showerheads with a flow greater than 2.5 gpm at 80 psig became effective in January 1994. However, testing in California has shown that even after regulations were enacted, not all new showerheads sold met the minimum requirements. We use a 20% value for

households with showerheads that exceed the maximum allowed by regulations, assuming that since 1999 more households have installed low-flow showerheads. In addition, the *REUW* study notes that their data might over estimate shower flows because "many showers start at a high flow rate as water is run through the bathtub spigot and the temperature adjusted, then the flow is restricted when the shower diverter valve is used and the flow is constricted through the showerhead".

Percent of Showerheads that have been Tampered With
Because statistics on this do not exist, we used a value from a PG&E report as a proxy. The PG&E study found that of households participating in a retail coupon program, 6% did not use or had removed the purchased low-flow showerheads. We assume an uncertainty range of 0% to 12%, with a most likely and mean value of 6%.

Percent of Households having low flow showerheads
Based on the *REUW* study that showed 24% showered exclusively above the low-flow range, it is implicit that 76% have showerheads may be in compliance with low-flow showerhead regulations. If a household showers exclusively above the maximum flow rate, then they do not have a low-flow showerhead. If they sometimes shower below the maximum flow rate they then either: (1) throttle back the flow, (2) have at least one low-flow showerhead or (3) have low-flow showerheads in all showers. It is therefore possible that 76% low-flow saturation is on the high side for 1999. It may also be the case that since the 1999 study more households have installed low-flow showerheads. To be consistent, we assume that the percentage of households having low-flow showerheads are all those not exceeding the maximum allowed flow rates, or 80%.

Percent of Households with Multiple-head Showerheads
Recognizing a need for better data, the Plumbing Manufacturer Institute (PMI) sponsored a survey by W&W Services, Inc. The results of the survey asking PMI members the percentage of shower installations that contain any combination of two or more showerheads, body sprays or other outlets conveying water for showering, is as follows:

Percent of showers with two or more showerheads, body spas or other outlets conveying water for showering in -	Average
New construction	4.8%
Existing that are retrofitted	5.7%
Existing shower compartments	3.7%

Based on the PMI data, this scenario assumes that sales of multihead showerheads continue such that eventually the saturation across households reaches 4.3%, with an uncertainty range of 3% to 6%.

Tub Spout Leakage (old and new)
We use an estimate based on the difference between the previously maximum allowed leakage and current allowed leakage in California. California requires manufacturers of tub spouts to submit test data, which the CEC makes publicly available on their web site.

Percent of all showers having a tub spout.
In the *REUW* study 62% of showers were part of a shower-bathtub. We assume that these had a tub spout of the type that can leak when the shower is in use (i.e., not completely separate from the shower piping).

Percent of tub spouts not in compliance with CEC requirements.
Tub spouts are regulated in California but not by the Federal government. Lacking any definitive national data, we assumed that the share of tub spouts that are not in compliance with the California standard on a nationwide basis is between 0 to 10 percent, with an average of 5%.

Percent of time a shower is used that also has a tub spout.
We multiply the percentage estimated not to be in compliance by the percentage of time the tub shower combination is used in houses that also have a shower-only option. The value includes the fraction of homes that have a shower-only option.

Percent time multi-heads are used at the same time or used instead of a single-head shower in the house.
Some of the multi-head shower systems are meant for a luxury shower experience and not for a quick shower. Sales of these systems may increase in the future, especially when they are sold as DIY projects at large merchandisers. It is recognized that many residences have more than one shower and that while one shower may have multiple showerheads, another may be a conventional shower with a single showerhead. In this study we assume that 50% to 100% (on average 75%) of all showers in homes with multi-head shower systems are taken in the shower having multiple showerheads.

Electricity Rate, Natural Gas Rate, Water & Wastewater Rate
Single average values were used in this study because we are interested only in the average national rates and not the variability for individual households. The electricity and gas rates are the national averages used by the Federal government on energy efficiency labels in 2005. The average national water rate is based on the 2001 Department of Energy rulemaking for clothes washers and updated to 2004 using Raftellis data [11] [12].

Percentage of Water Heaters using Gas and Percentage using Electricity
Based on data from the Department of Energy's 2000 Technical Support Document for Clothes Washers (with data normalized to only gas and electric water heaters), we used a gas water heater share of 58% and an electric water heater share of 42%.[13]

4.3 Baseline Water and Energy Consumption

National-average showerhead water consumption per day is estimated as follows.

> *Person-showers per day = (population) x (showers per day per person)*
> Where:
> *Population* = 290 million
> *Showers per person per day* = 0.70

Gallons per shower = shower flow (gpm) x length of shower (min.)
Where:
Shower flow rate = 2.2 gpm
Length of shower = 8.2 minutes

Person-showers per day are multiplied with gallons per shower to obtain the estimate of approximately 3.7 billion gallons of water used daily in showering.

4.4 Scenarios Ranked by Water-Saving Potential

The following sections discuss each scenario and provide the equations used in calculating the nationwide water use or savings. A distribution and range of savings are calculated in a spreadsheet.

4.4.1 Scenario 1: Change all showerheads that meet standard to operate below standard (from 2.5 to 2.0 gpm)

In this scenario, all showerheads that meet current standard would be replaced by showerheads having an even lower flow (2.0 gpm).

Assumptions: One cannot simply calculate the difference in flow rate between a standard showerhead and a lower-flow showerhead as measured in a laboratory, because field measurements show that showerheads are not always run at maximum flow rate. A throttling factor is used to correct for this difference. Although consumers who have lower-flow showerheads may take longer showers, in these calculations shower duration is assumed to remain constant. The following additional assumptions are made:

- 80% of the population has a 2.5-gpm rated showerhead.
- Only the 2.5-gpm showerheads will be converted to 2.0 gpm.
- The throttling factor is 0.9. This means that consumers do not open the water valves completely, and therefore use less than the rated showerhead flow.

Calculations:

Potential Water Savings =
(population)(showers per capita per day)(% of pop. having a 2.5-gpm rated showerhead)(delta flow)(throttling)(shower duration)
= (290,000,000)(0.70)(80%)(2.5 - 2.0 gpm)(0.9)(8.2 min.)
= 599 million gallons per day

4.4.2 Scenario 2: Change all showerheads that exceed standard to meet standard

This scenario assumes that all showerheads that currently operate above standard are replaced by showerheads having a flow rate that meets standard (2.5 gallons per minute @ 80 psig).

Assumptions:

- 4.0 gpm is average for rate of flow for non-compliant showerheads.
- 2.2 gpm is the actual flow with compliant showerheads.

- Savings in flow for each showerhead changed to be compliant = (4.0 - 2.2 gpm) = 1.8 gpm

Calculations:

Savings per shower = *(1.8 gpm)(8.2 min.) = 14.8 gallons per shower*

Potential Water Savings =
(percent above standard)(population)(showers per capita per day) (gallons per shower)
(20%)(290,000,000)(0.70)(14.8 gal)
= 601 million gallons per day

4.4.3 Scenario 3: Reduce average shower time by 1 minute

In this scenario we postulate that the length of a shower would be reduced by one minute if the showerhead gave a more satisfying shower. For example, anecdotal reports indicate that consumers spend more time rinsing long hair when using a poorly designed low-flow showerhead. Selection of better performing showerheads could be aided by having an unbiased database with showerhead performance data or by distribution of better showerheads in utility rebate or give-away programs.

Assumptions: This scenario assumes that better-performing showerheads will result in a reduction of average shower length of one minute. We assume the flow rate of the showerhead remains the same at 2.2 gpm (the improved performance of the showerhead is a function only of its design).

Calculations:

Potential Water Savings =
(population)(showers per day per capita)(flow rate)(reduction in shower time)
= (290,000,000)(0.70)(2.2 gpm)(1 min.)
= 447 million gallons per day

4.4.4 Scenario 4: Counteract the trend toward using multiple showerheads, body spas, etc.

A recent trend in shower design for both residential and hotel applications is to "upgrade" to multiple showerheads controlled by one on-off lever. A related trend is to have more than one showerhead per shower stall, each with its own control valve presumably operating within the regulatory standard. (Various terminology is used to describe multiple-head and high flow showerheads including rain systems, body spas and shower towers. These are illustrated in Appendix D.) This scenario estimates the savings due to reducing the sales of multi-heads.

A review of manufacturer and industry Web sites reveals that some showerhead systems are advertised as supplying as much as 10 gpm of flow. Other shower systems produce a waterfall or rain-type of effect, or have a series of water jets mounted on a vertical wall. Through these and other systems that use a pump to recirculate large amounts of water, shower producers can now advertise a shower experience that is equivalent to standing up in a whirlpool.

Assumptions:

- Without efforts to counteract the trend toward multiple-showerhead systems, an average of 4.3% of showers (stalls) will have a multi-head showerhead, body spa type shower or other type of high flow showerhead.
- Based on a sampling of Web site data, we assume that these high-flow showerhead systems use an average of 5.5 gpm.
- A high-flow showerhead replaces a showerhead having an actual (not rated) flow of 2.2 gpm.
- Those households having a multi-head showerhead use it 75% of the time. The rest of the time they use another shower stall.

Calculations:

Potential Water Savings =
(population)(showers per capita per day) (gpm reduction)(% replaced by high-flow showerheads)(shower duration)(fraction of time this shower stall is used)
= (290,000,000)(0.70)(5.5 - 2.2 gpm)(4.3%)(8.2 min.)(0.75)
= 177 million gallons per day

The calculated water savings represent a yearly savings after sales equilibrium has been reached, i.e., after the lifetime of a showerhead. The estimated lifetime of a low-flow showerhead is 10 to 15 years.

4.4.5 Scenario 5: Reduce number of showerheads tampered with (modified to increase water flow)

This scenario assumes that some low-flow (compliant) showerheads were installed but later removed or modified so that flow rate exceeds standard. We assume that consumers tamper with their showerheads when performance is unsatisfactory, and that adequate information on showerhead performance would assist consumers in purchasing water-efficient showerheads that operate satisfactorily. The dominant 'tampering' practice is the removal of the flow restrictor where that is possible.

Assumptions: We use a number from a Pacific Gas and Electric Company (PG&E) study that found that 6% of showerheads that were part of a replacement program were removed or not used.

Calculations:

Potential Water Savings =
(% tampered)(population)(showers per capita per day)(delta flow)(shower duration)
= (6%)(290,000,000)(0.70)(3.5 - 2.2 gpm)(8.2 min.)
= 130 million gallons per day

4.4.6 Scenario 6: Reduce tub spout leakage

Showers that are plumbed as part of a bathtub typically start with water flowing through the spout. Water is then diverted to the showerhead via a lever connected to the tub spout. Although most of the water is diverted to the showerhead, throughout the shower some water escapes through the tub spout. Leakage through the tub spout reduces the amount of water available to the showerhead, reducing showerhead performance. In this calculation we assume that the total flow (through the showerhead and tub spout) is increased by the amount of water leaking through the tub spout. (Due to the water lost through the tub spout a consumer may also take longer showers, or increase the water temperature.) The California Energy Commission (CEC) established regulations stipulating the maximum allowable tub spout leakage, as shown in Table 3 below.

Table 4: Allowable Tub Spout Leakage in California

Effective Date	Allowable Leakage when New	Allowable Leakage after 15,000 Cycles
March 1992	0.1 gpm	0.3 gpm
March 2003	0.01 gpm	0.05 gpm

Assumptions:

- Showers having a tub spout diverter represent 62% percent of all showers.
- New tub spouts follow California requirements, over a lifetime leaking an average of 0.03 gpm (between the allowable leakage when new and after 15,000 cycles).
- Baseline leakage nationwide is represented by an average of California's 1992 requirements (0.1 gpm when new and 0.3 gpm after 15,000 cycles), or 0.2 gpm.
- The percentage of tub spouts nationwide that conform to California's March 2003 specifications is unknown; we assume that 5% do not conform.

Calculations:

Δ *leakage = (0.2 - 0.03 gpm) = 0.17 gpm*

Potential Water Savings =
(% not conforming with CEC)(population)(shower per day per person)
(% showers with tub spout)(delta tub spout leakage)(shower duration)(% time a shower with a tub spout is used when one is available)
= (5%)(290,000,000)(0.70)(62%)(0.17 gpm)(8.2 min.)(50%)
= 4.4 million gallons per day

5.0 POTENTIAL ENERGY SAVINGS

In a simplified analysis, it can be reasonably assumed that the energy savings are proportional to the water savings. This assumes that any change in flow rate does not affect the temperature setting that the consumer uses. In this analysis we assume that 42% of water heaters are electric and have a recovery efficiency of 98%, and that 58% of water heaters are natural gas-fired and have a recovery efficiency of 75%. Other assumptions are a cold water inlet temperature of 60˚F (based on DOE test procedures for water heaters) and a shower temperature of 105˚F, which is commonly used.

Calculations:
Energy required for electrically heated water =
[(1 gal.)(8.3 lbs/gal)(1 Btu/lb/˚F)(105˚F - 60˚F)] / (0.98)
= 381Btu/gallon
= 0.112 kWh/gallon
= 112,000 kWh per million gals

Energy required for gas-heated water=
[(1 gal.)(8.3 lbs/gal)(1 Btu/lb/˚F)(105˚F - 60˚F)] / (0.75)
= 498 Btu/gallon
= 4980 Therms per million gals

6.0 RESULTS

Results in Tables 4 and 5 below show the potential water and energy savings for each of the analyzed scenarios. Because the potential water savings are sensitive to specific parameters used in the calculations, they should be viewed as rough estimates. Sources of uncertainty include differences in results from various field studies and a lack of data. For example, in the case of tub spouts, the leakage rates reported by manufacturers need to be verified by independent testing. Nevertheless, the values are useful for an initial ranking of potential showerhead conservation programs. Note that savings from different scenarios are not additive.

Table 5: Potential Water Savings for Each Showerhead Scenario

Scenario		Percent [1] savings of water			Average million gallons per day savings		
		Average	Range Minimum	Range Maximum	Average	Range Minimum	Range Maximum
1	Change all showerheads that meet standard to below standard (from 2.5 to 2.0 gpm)	16.4%	13.1%	20.4%	599	478	751
2	Change all showerheads that exceed standard to meet standard	16.4%	4.3%	33.8%	596	185	1222
3	Reduce average showering time by 1 minute	12.2%	11.9%	12.5%	447	380	520
4	Counteract the trend toward using multiple showerheads body spas, etc.	4.9%	0.2%	19.5%	177	11	631
5	Reduce number of showerheads tampered with (modified to increase the flow)	3.5%	0.0%	10.5%	131	2	384
6	Reduce tub spout leakage	0.1%	0.0%	0.5%	4	0	19

(1) Percentage of baseline showerhead water use

Table 5 shows the energy savings based on all electric water heaters (essentially the energy content of the water). The monetary benefits shown are based on the nationwide mix of gas and electric water heaters and their respective efficiencies. This analysis does not consider any changes in showerhead costs connected with the scenarios.

Table 6: Potential Energy Savings for Each Showerhead Scenario

Rank	Scenario	Energy Savings in Gigawatt hours per day (GWh) (1)		
		Average	Range Minimum	Range Maximum
1	Change all showerheads that meet standard to below standard (from 2.5 to 2.0 gpm)	66.9	53.4	83.9
2	Change all showerheads that exceed standard to meet standard	66.6	20.7	136.5
3	Reduce average showering time by 1 minute	49.9	42.4	58.1
4	Counteract the trend toward using multiple showerheads body spas, etc.	19.8	1.2	70.4
5	Reduce number of showerheads tampered with (modified to increase the flow)	14.7	0.3	42.9
6	Reduce tub spout leakage	0.5	0.0	2.2

(1) The energy savings shown here assumes electrically heated water.

Table 7: Potential Annual Dollar Savings for Consumers for Each Showerhead Scenario

Rank	Scenario	Millions of Dollars in Water and Energy Savings (1)		
		Average	Range Minimum	Range Maximum
1	Change all showerheads that meet standard to below standard (from 2.5 to 2.0 gpm)	2,317	1,816	2,913
2	Change all showerheads that exceed standard to meet standard	2,313	743	4,639
3	Reduce average showering time by 1 minute	1,726	1,464	2,006
4	Counteract the trend toward using multiple showerheads body spas, etc.	693	32	2,653
5	Reduce number of showerheads tampered with (modified to increase the flow)	503	5	1,435
6	Reduce tub spout leakage	17	0	76

(1) Assumes 42% electric water heaters, 58% gas water heaters and includes the cost of water.

7.0 COST OF UTILITY PROGRAMS

Implementation costs of showerhead programs vary on the specific program designs. Labor and material costs for installing low-flow showerheads in a utility-sponsored direct installation or audit program ranged from $12 to $30 per installation[14]. The time needed was 30 to 45 minutes. Programs that provide showerheads by mail or allow them to be picked up are less costly.

While all of these methods listed below cost in the range of $7 to $30 per household, the customer participation rates can vary greatly[15].

- Door-to-door canvas
- Mass Mailing
- Depot Pickup
- Rebates
- Kit Requests
- Special event giveaways (fairs, exhibits, etc.)

Alternately, some of the benefits may be achieved by an informational campaign or by testing and listing the performance of showerheads on a web site.

8.0 COST / BENEFIT CONSIDERATIONS

Costs-benefit ratios of enacting the six projects described above can be evaluated in terms of:

- the cost to the consumer of a better showerhead compared to the amount the consumer saves in water and energy costs
- the cost to a utility company of a research and education program or a showerhead replacement program compared to the value of the water conserved

In the second case, a utility generally seeks to conserve water (or energy) because of a shortage. A cost-benefit analysis can be used to help decide which programs to implement first. In some cases a utility's cost might only involve constructing a database or enforcing standard rather than initiating a replacement program.

9.0 RELATIONSHIP BETWEEN RESEARCH OBJECTIVE AND PROGRAMS

Figure 1 illustrates some of the connections between research, programs and results. Specific research and testing options are outlined in a separate LBNL document, *Proposal for Showerhead Testing and Evaluation*.

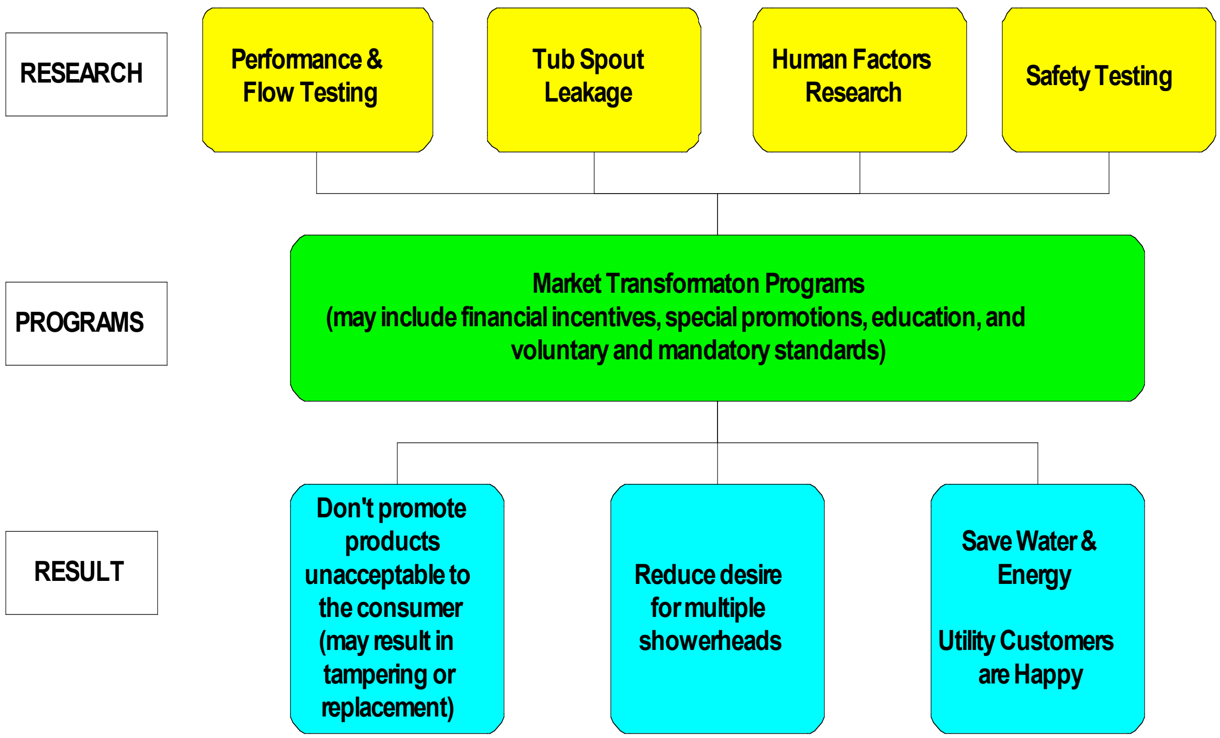

Figure 1: Linkages between Research, Conservation Programs and Results

10.0 LIMITATIONS OF THE STUDY AND DATA NEEDS

In this section we consider some of the important data limitations and the need for collection of better data.

Multi-head showers

A dearth of information exists for the scenario "percent of households with multiple-head showerheads". It is unknown how many showerheads of the multiple-head variety are used for the duration of the shower, and how many are part of systems that recirculate the water.[a] Also unknown is whether these shower systems encourage a longer shower time or if the capacity of the water heater to provide hot water limits the duration of the shower. There is also uncertainty on whether or not all showerheads in a shower are on at the same time if they are on separate valves. Even if we had a precise value for the number of households having a multiple shower as one of its showers, we would not know the percentage of the time this shower is used (in this report it is assumed to be 75% of the time on average).

[a] Some "body spa" shower types heat and recirculate the water, thereby increasing energy use without necessarily increasing the amount of water used.

Although we know from testing and advertising some high flow showerheads use more than 2.5 gpm at rated conditions – we do not know the sales distribution of these by flow rate. This data could be obtained by combining sales and marketing data (purchased from marketing companies such as the NPD Group [www.npd.com]) and combining this with independent showerhead test data.

In order to more accurately characterize possible future water use due to multi-head showers and body spas and the potential to limit it – the following data collection is essential:

- Percentage of households having a multiple showerheads
- Frequency of multiple head showerhead use
- Flow rate of multiple showerhead
- Total water volume of a multi-head shower event
- Duration of shower with multiple showerhead
- If this system is part of a "body spa" with recirculated water
- Future trends of multiple showerhead use
- Limits to flow due to (½ inch) pipe diameter and available water pressure (anecdotal evidence and limited showerhead tests indicate that this is not the limiting factor)
- Limits of water use due to size of water heater, and the effect of tankless water heaters on length of these showers
- Whether or not "body spas" are replacing conventional showers or whirlpool type tubs

The growing trend in tankless water heaters allows for a continuous flow of hot water. This in turn facilitates high-flow and multiple-head shower systems by satisfying there large hot water demands. Future analyses should include the effect of tankless water heaters on the amount of shower water used.

Tub spout leakage

Beyond the self-reported data compiled in the California Energy Commission database, little data is available on tub spout leakage. Data needs are comprised of the following:

- The number of tub spouts currently sold with more than the minimum allowed leakage.
- The amount of leakage of those currently sold and in violation of the regulation.
- Existing tub spouts that meet the old standard and how much they actually leak.
- How much a tub shower combination is used in houses that also have a shower only.

In a separate document, *Proposal for Showerhead Testing and Evaluation*, LBNL is proposing research to support programs aimed at reducing the water consumption and attendant energy consumption of poorly performing showerheads. These savings would pertain primarily to residences, but could also pertain to commercial and public facilities such as hotels, sports facilities and schools.

11.0 EVALUATION OF SHOWERHEAD PERFORMANCE

Although Federal regulations require showerheads to be water-efficient, not all models necessarily provide a satisfactory shower. Because consumers may modify or remove low-flow features, even efficient showerheads -if tampered with- may end up saving no water at all. Experiences with poorly performing showerheads may also act as a deterrent to the replacement of inefficient showerheads with new efficient showerheads.

Water efficient toilets also suffered initially from poor performance, but now reliable and realistic test methods are used to identify the better-performing models.[a] Given this information, consumers can replace inefficient toilets with efficient models that provide satisfactory performance. In addition, water utility sponsored programs can now recommend or specify the better performing toilets in rebate programs.

A comparable method is needed to evaluate showerhead performance and develop a database of efficient, effective showerheads. Simply listing low- and high-flow showerheads is unlikely to be sufficient, because some consumers might believe that high-flow showerheads provide a better shower experience. A database that rated the performance of showerheads might encourage consumers to purchase the better-performing models, and not to try to defeat the flow-restricting parts. This database must then be maintained in order to continue to provide updated information through a web site or other means easily accessible to the public.

12.0 CONCLUSIONS

The analysis of showerheads described here indicates that significant water and energy savings are possible in U.S. homes. Measures to reduce showerhead water use have potential for savings of up to 16% of all shower water use. These measures include reducing the flow of showerheads and improving their performance, which may reduce shower length thereby saving water.

Uncertainties exist regarding the magnitude of the savings, particularly with respect to reducing the impact of multi-head or spa type showers on national shower water use. However, the results are robust enough to warrant further research on shower water conservation, which will help stakeholders prioritize water conservation programs.

ACKNOWLEGEMENTS

The author acknowledges Steven Meyer and Jim McMahon for their help in reviewing and editing this document.

[a] http://www.cuwcc.org/Uploads/product/MaP-Final-Report.pdf

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[3] Mayer P., DeOreo W., et. al. 1999. *Residential End Uses of Water*, American Water Works Association Research Foundation, p. xxvii

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[9] U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December 2000, p. 3-14

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[12] Raftellis Environmental Consulting Groups, AWWA 2004 Water & Wastewater Rate Survey, Charlotte, NC

[13] http://www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html

[14] Vickers, Amy. *Handbook of Water Use and Conservation*, 2001, p. 95

[15] Vickers, Amy. *Handbook of Water Use and Conservation*, 2001, p. 95

APPENDICES

A. Current Regulations

U.S. Department of Energy (DOE) regulations specify that the test procedures for testing showerhead water use are as in ASME/ANSI Standard A112.18.1M-1996. As of January 1, 1994, the maximum water use allowed for any showerhead is 2.5 gallons per minute when measured at a flowing pressure of 80 pounds per square inch gauge.

ANSI/ASME standard A112.18.1M-1996, Section 7.4.4 on showerheads, states that "shower head volume controls, whether integral or separate, shall be designed so that they cannot completely shut off the water to the shower head." This requirement is intended to eliminate thermal shock when the shower is turned back on by the user. Some showerheads on the market have a partial shut off valve on the showerhead that reduces the flow considerably and is meant to be used to turn down the water flow while lathering.

The California Energy Commission (CEC) in addition to supporting Federal regulations, has additional leakage requirements for tub spouts.

B. Conversion Factors

Conversions	
1 acre-foot	326,000 gallons
1 kWh	3412 Btu/hr
1 Gigawatt hour (GWh)	One million kilowatt hours (kWh)

C. Additional Resources

Waste Not Want Not: The Potential for Urban Water Conservation in California, Gleick, P., Pacific Institute:
http://www.pacinst.org/reports/urban_usage/appendices.htm

The World's Water 2004-2005, Gleick, P., Island Press, 2004.

D. Definitions of Showerhead and Shower System Terms

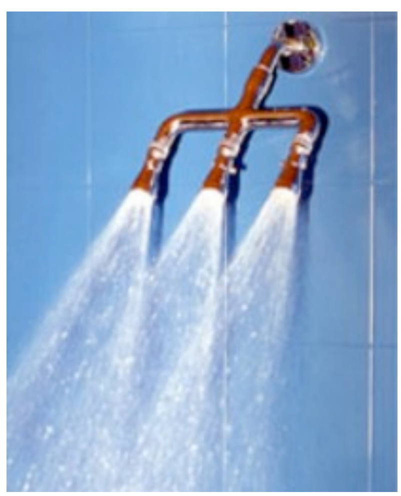
Single head

This type of showerhead may have a single setting or more than one setting. Settings often include more and less focused sprays and a pulsating spray. The photo below shows the showerhead selected by Holiday Inn based on its performance in terms of coverage and pressure.

Single showerhead fixture –Kohler

Multiple-head Shower

These fixtures may have two or more spray nozzles connected to one pipe. They can easily replace a single head fixture.



Multiple showerhead fixture- source: http://www.neatitems.com/triple_showers.htm

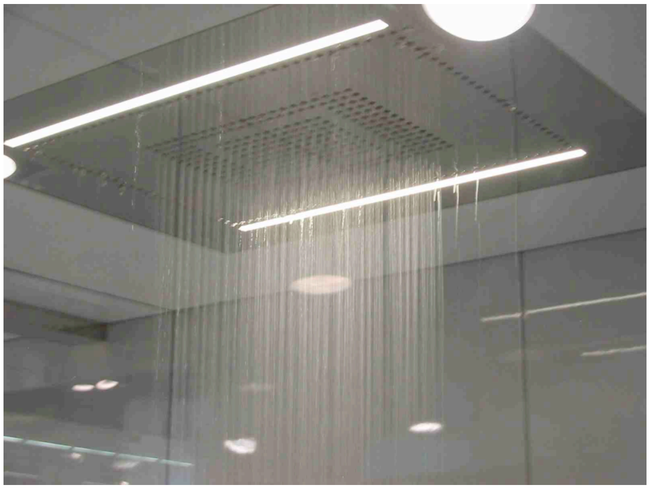
Cascading Showerhead
These are also referred to as “rainshower” and “downpour” type fixtures. They often are mounted overhead such that the water drops straight down. They typically give a softer spray and have diameters of 6 to 8 inches. They are less likely to have more than one spray setting. The model shown below has 80 spray nozzles.

Cascading showerhead- Consumer Reports, Hansgrohe Raindance

Shower Panel or Shower Tower
These are designed to spray water from more than one location having more than one showerhead. They may operate sequentially or as the photo shows below all at one time. Some are designed for the homeowner to replace an existing single pipe fixture and some are designed to be professionally installed with all piping behind the walls.

Shower panels – source https://my.estorenw.com

Rain Systems
As shown in the photograph below, rain systems simulate rain by allowing water to fall from an overhead fixture.



Rain system – source John Koeller

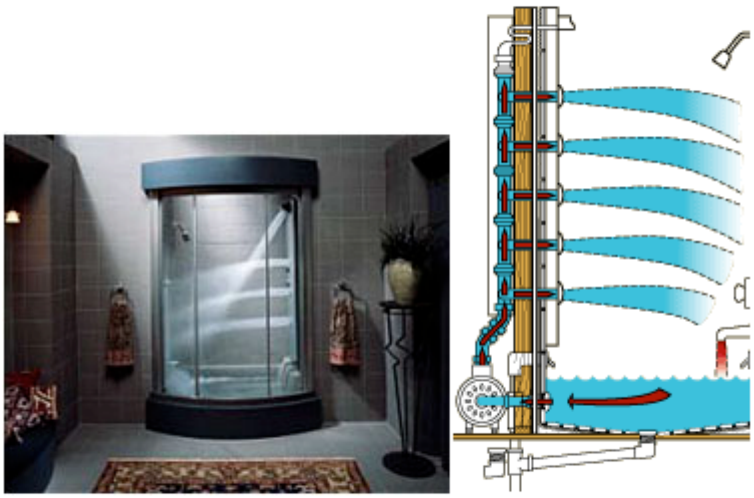
Body Spas
Body spas consist of multiple showerheads and are described by some as the vertical equivalent of a spa. The showerheads may be activated sequentially or intermittently.

The number of showerheads that are active can sometimes be controlled by the user via controls or may be set to automatically vary the spray pressure and temperature.

Body spas – sources: Kohler Body Spa Systems & Santa Cruz Sentinel, March 21, 2005

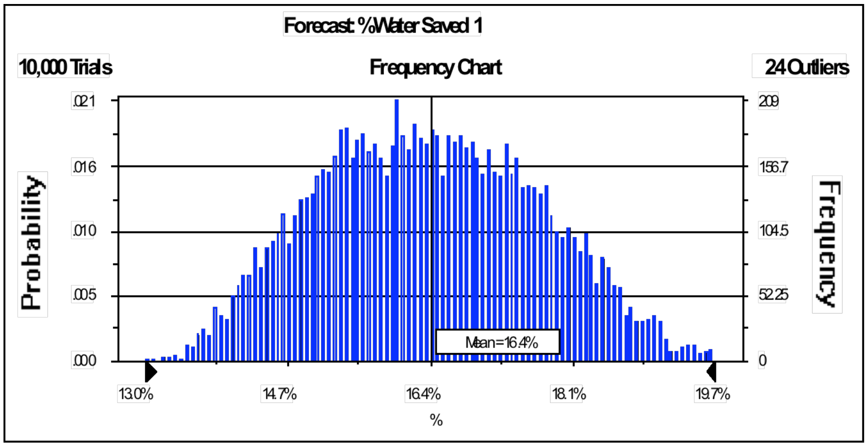
Recirculating System

In some cases the water in a body spa is recirculated and the shower system has its own heater and pump system. When used in this mode, it is not meant for cleaning. The recirclulating feature can typically be disabled to allow use as a shower.

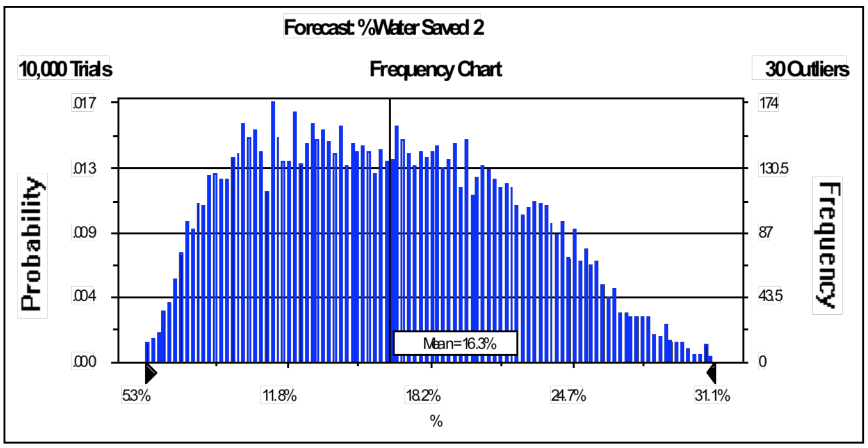


Body spa with recirculation – source: Kohler Body Spa Systems web site

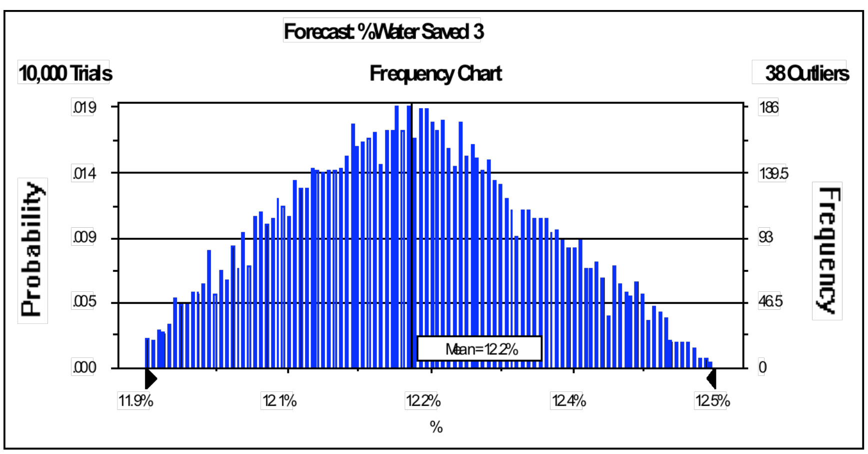
E. Output Probability Distributions



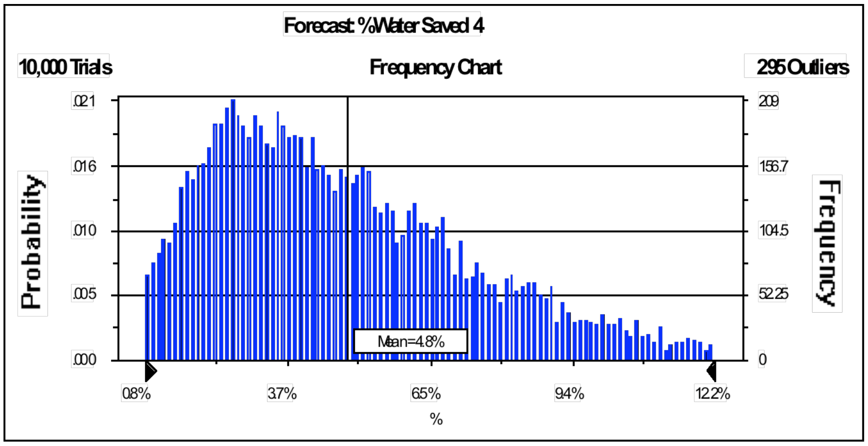
Scenario 1: Change all showerheads that meet standard to below standard



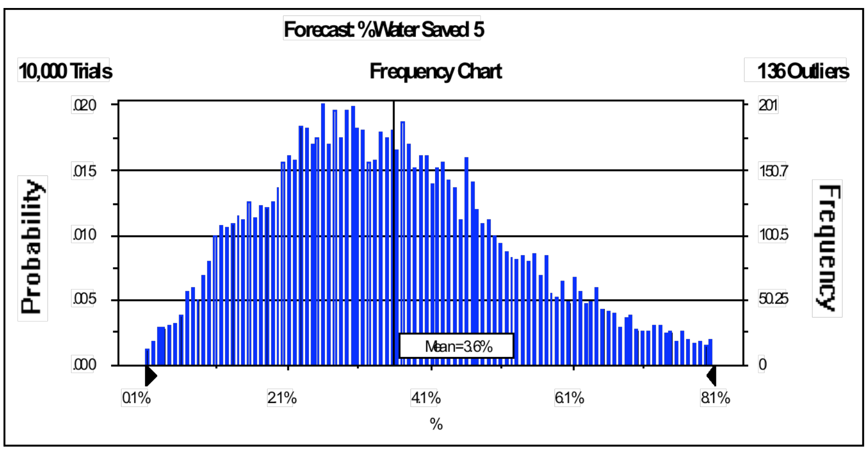
Scenario 2: Change all showerheads that exceed standard to meet standard



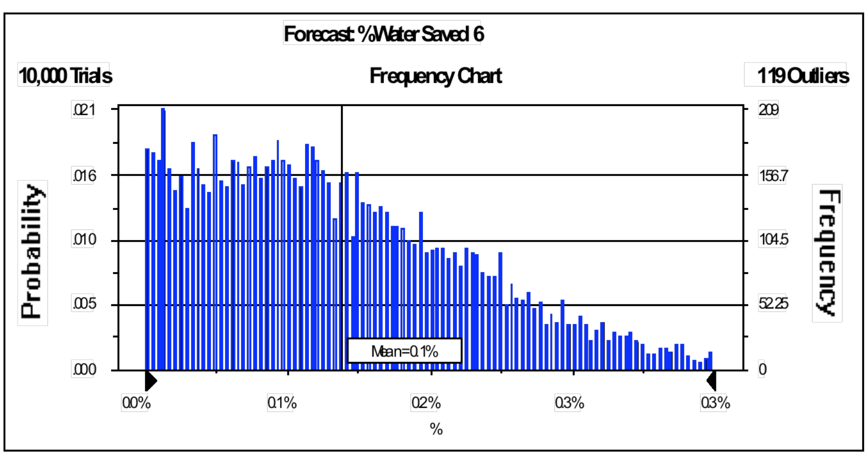
Scenario 3: Reduce average showering time by 1 minute



Scenario 4: Counteract the trend toward using multiple showerheads
Body spas, etc.



Scenario 5: Reduce the number of showerheads tampered with



Scenario 6: Reduce tub spout leakage