Faucets

Codes and Standards Enhancement (CASE) Initiative
For PY 2013: Title 20 Standards Development

Analysis *of* Standards Proposal for
Residential Faucets and Faucet Accessories

Docket #12-AAER-2C

CASE Report
July 29, 2013

Prepared for:

PACIFIC GAS & ELECTRIC COMPANY

SOUTHERN CALIFORNIA EDISON

SAN DIEGO GAS AND ELECTRIC

SOUTHERN CALIFORNIA GAS COMPANY

NATURAL RESOURCES DEFENSE COUNCIL

Prepared by:
Ethan Guy, Heidi Hauenstein and Sarah Schneider, ENERGY SOLUTIONS
Tracy Quinn and Ed Osann, NATURAL RESOURCES DEFENSE COUNCIL

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Acknowledgements

The CASE Team would like to thank Gary Klein (Affiliated International Management, LLC), John Koeller (Koeller & Company), and Michael Read (Oak Lodge Sanitary District) for their contributions in the development of this standards proposal.

Table *of* Contents

1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standard options for residential faucets and faucet accessories.

California consumes about 2.9 trillion gallons of water per year for urban uses (Christian-Smith, Heberger & Luch 2012). Urban uses include outdoor and indoor residential water use; water used in commercial, institutional, and industrial applications; and unreported water use, which is primarily attributed to leaks. The 2.9 trillion gallons of water is associated with approximately 26.4 terawatt hours of embedded electricity, which is required for water supply, conveyance, potable water treatment and distribution, and wastewater collection and treatment.

Faucets are the third largest use of residential indoor water use. It is estimated that water used in faucets accounts for about 20 percent of all residential indoor water use. For this reason, reducing the amount of water used in faucets is a key component of California's water reduction strategy. Establishing efficiency standards for residential faucets will have a significant impact on California's overall water and embedded energy use.

For the past several years there has been a national trend towards the production of more efficient faucets and faucet accessories, particularly since 2007 when the United States (U.S.) Environmental Protection Agency's (EPA) WaterSense® program established a voluntary specification for high-efficiency lavatory faucets. Though there has been a shift towards lower flow faucets, it has not come at the expense of faucet utility (i.e. performance as it relates to high consumer satisfaction). As the market has shifted toward more efficient products, the opportunity to achieve even larger water and energy savings through efficiency standards has become a viable option.

The proposed Title 20 code change presented in this report would revise the water efficiency standards for residential lavatory and kitchen faucets. The proposed standard for lavatory faucets would be a maximum flow rate of 1.0 gallon per minute (gpm) tested at a water pressure of 60 pounds per square inch (psi) and a minimum flow rate of 0.5 gpm at 20 psi. The proposed standard for kitchen faucets is a maximum flow rate of 1.8 gpm with an allowance for dual flow accessories that temporarily increase the flow rate to 2.2 gpm.

The year the faucet stock turns over (2024), the proposed standards would result in projected annual savings of over 44.8 billion gallons of water, which has an associated embedded electricity savings of 451 gigawatt hours. The standards would also result in an annual savings of 234 GWh and 149 million therms from hot water savings. Electricity demand would be reduced by 53.5 MW. These savings estimates reflect the savings that would be achieved from all faucets installed in California in 2024 (see Table 1.1).

Table 1.1 Estimated Energy and Water Savings

Product Class	Stock				
	Water Consumption (million gal/yr)	Natural Gas Consumption (million therms/yr)	Electricity Consumption (GWh/yr)	Embedded Electricity Consumption (GWh/yr)	Electricity Demand Savings (MW)
2015 (first year standard is in effect)					
Lavatory Faucets	2,933	10	15	29	3.5
Kitchen Faucets	1,320	4	7	13	1.6
Total	**4,253**	**14**	**22**	**43**	**5.1**
2024 (year stock turns over)					
Lavatory Faucets	30,953	103	162	311	36.9
Kitchen Faucets	13,907	46	73	140	16.6
Total	**44,860**	**149**	**234**	**451**	**53.5**

2 Background

2.1 Regulatory Background

2.1.1 Federal Regulatory Background

Prior to the first efficiency standards taking effect, some faucets used as much as 7 gallons per minute (gpm). In the 1980s and early 1990s several states, including California, had established water efficiency standards for faucets.[1] Congress used these state-level standards as the basis for the first federal standards that were enacted by the Energy Policy Act of 1992 (EPAct 1992) that took effect in 1994 and set the maximum allowable flow rate for lavatory and kitchen faucets at 2.2 gpm at 60 psi (EPAct 1992).

EPAct 1992 states that if the American Society of Mechanical Engineers (ASME) revises its standards for plumbing fixtures and fittings, the U.S. Department of Energy (DOE) must review ASME's action and consider adjusting the federal standards. If ASME does not revise its standards within five years, states are allowed to set more stringent state-level standards. To date, ASME has not revised the faucets standards. Since ASME did not revise the standard within five years of the first effective date, states were eligible to set their own standard after 1999.

On December 22, 2010, the DOE officially waived federal preemption for energy conservation standards with respect to any state regulation concerning the water use or water efficiency of faucets, showerheads, water closets, and urinals (75 Fed. Reg.245, 22 December 2010). This waiver allows states to set their own standards for the relevant plumbing products as long as the state standard is more stringent than the federal standard.

2.1.1 California Regulatory Background

On February 28, 2008 Governor Schwarzenegger outlined key elements of a comprehensive water conservation plan to address water issues in the Sacramento-San Joaquin Delta. From this effort, the State Water Resources Control Board (SWRCB) began developing the 20x2020 Water Conservation Plan (Plan), which called for a 20 percent reduction in per capita urban water use by 2020. In turn, the draft Plan laid the foundation for The Water Conservation Act of 2009 (Senate Bill X7-7, Steinberg 2009), which was enacted in November 2009; this codified the 20x2020 goal. In February 2010, the SWRCB released the Final 20x2020 Water Conservation Plan, which details how the State will achieve its 20x2020 goal. The Plan includes a recommendation to establish more stringent water efficiency standards for plumbing fixtures and fittings. Specifically, the Plan states: "Given the state's water supply challenges, appliance efficiency codes must remain ahead of the rest of the nation" (SWRCB 2010).[2]

Pursuant to California Public Resources Code, Section 25402, the CEC is required to address the reduction of wasteful, uneconomic, inefficient or unnecessary consumption of energy, including the energy associated with the use of water. Section 25402 gives the CEC authority to set water

---

[1] Effective December 22, 1978, California law required all faucets to consume no more than 2.75 gallons per minute (gpm) tested at 20 – 80 pounds per square inch (psi) (CEC 1978).

[2] More information about California's 20x2020 goal and the plan to achieve this goal is available on the State Water Recourses Control Board website: http://www.swrcb.ca.gov/water_issues/hot_topics/20x2020/ and the Department of Water Resources website: http://www.water.ca.gov/wateruseefficiency/sb7/.

efficiency standards for appliances. Thus, the CEC is mandated to establish and enforcing standards that will reduce statewide water consumption (Cal. PRC §25402).

In 2010, mandatory faucet efficiency standards were introduced to the California Green Building Code, which is also known as CALGreen or Part 11 of Title 24. The 2013 CalGreen standards, which take effect in January 2014, include requirements that newly constructed residential buildings install faucets that meet a minimum efficiency level.

2.2 The Importance of Water Efficiency in California

Water is essential to supporting and sustaining the environmental, economic, and public health needs of the State. Ongoing drought, shifts in regional climate patterns, and the State's population growth have increased demand for water. In addition, the demand for more energy also increases the demand for water used to produce electricity. Without reductions in water use, water-related energy use is projected to continue increasing (California Sustainability Alliance 2013). Thus, the installation of water-saving devices in residential, commercial, and industrial applications is extremely crucial for addressing California's water resource needs. Water use efficiency and conservation protects the future of our State's water supply for communities, businesses, industry, and the environment.

Multiple benefits come from using less water and from using it more efficiently. In addition to reducing the demand of available and shrinking water supplies—which enhances water supply security—use water use efficiency and conservation help to decrease the need to invest in costly, large-scale infrastructure projects (e.g., dams, canals, reservoirs) while also reducing operating costs for water utilities (e.g., pumping and treatment) (U.S. EPA 2013). Furthermore, decreasing the amount of water that is wasted improves water quality and helps us maintain higher water levels in lakes, rivers and streams, which protect human health and the environment (WaterSense 2013b). On the demand side, water use efficiency lowers household energy and water bills. And efficient water use also has indirect benefits, such as improved air quality through reduced energy requirements for pumping (The Alliance for Water Efficiency 2012) and a reduction in the amount of greenhouse gases emitted in the production of energy and the conveyance, treatment, and heating of California's water.

2.3 Embedded Energy in California's Potable Water

California consumes about 2.9 trillion gallons of water per year for urban uses (Christian-Smith, Heberger & Luch 2012). Urban uses include outdoor and indoor residential water use; water used in commercial, institutional, and industrial applications; and unreported water use, which is primarily attributed to leaks. The 2.9 trillion gallons of water is associated with approximately 26.4 terawatt hours of embedded electricity.

As shown in Figure 2.1 and Figure 2.2 below, residential faucets consume about 171 billion gallons of water per year, which is associated with an embedded electricity use of 1,719 GWh per year.

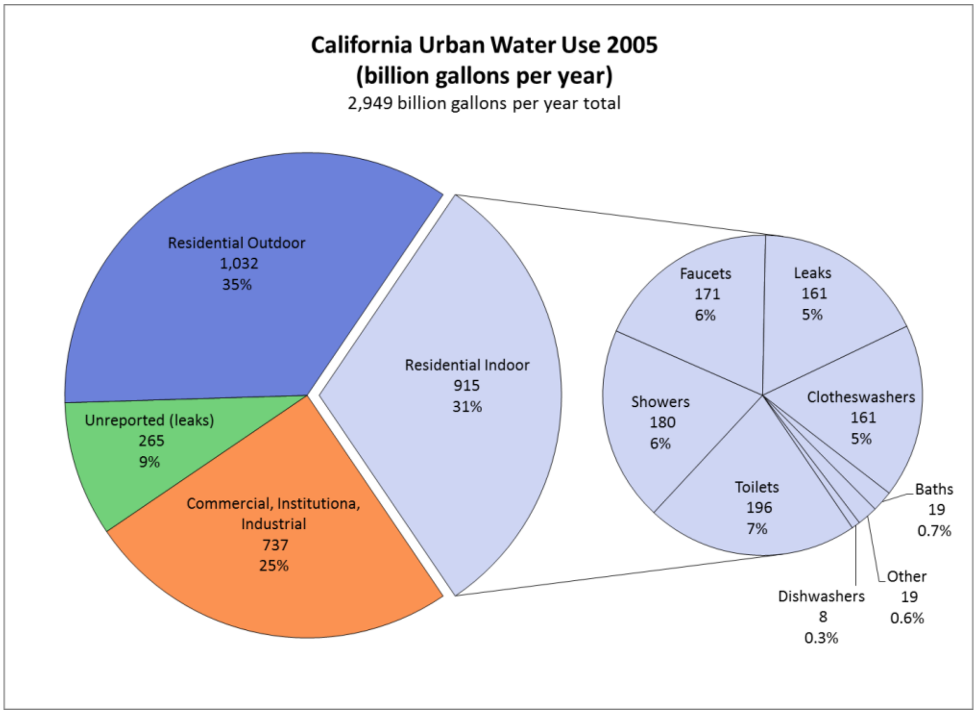


Figure 2.1 California Urban Water Uses (2005)

Source: Christian-Smith, Heberger, Luch (2012)

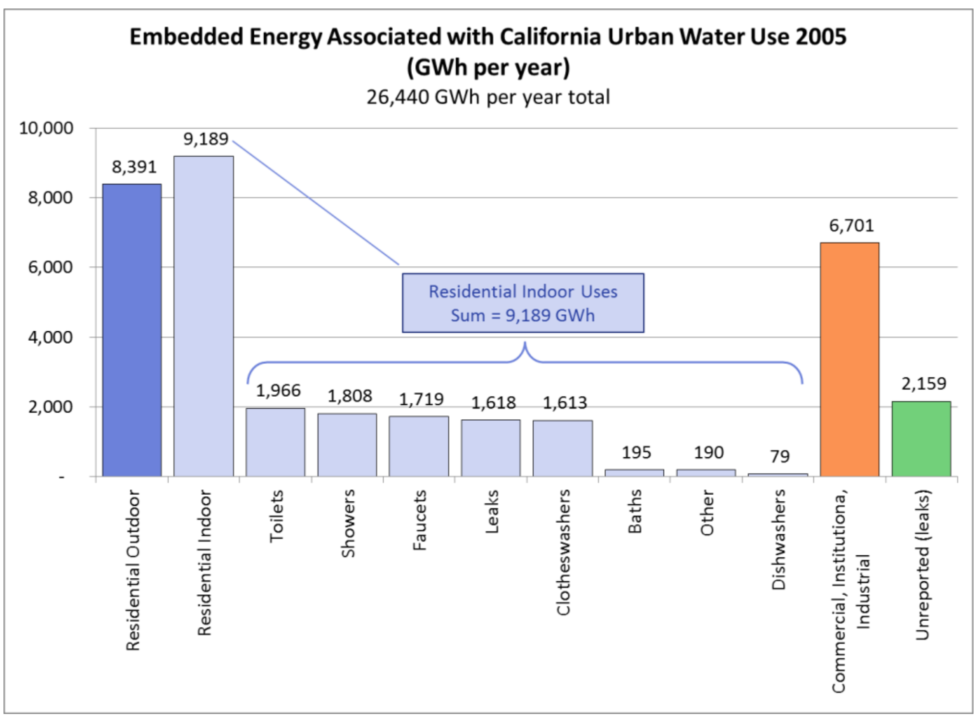


Figure 2.2 California Urban Water Uses (2005)

Source: Christian-Smith, Heberger, Luch (2012).

Assumptions: Embedded energy factor of 8,134 kWh/MG for residential outdoor water use and unreported (leaks); embedded energy factor of 10,045 kWh/MG for residential indoor; embedded energy factor of 9,090 kWh/MG for commercial, institutional, industrial.

3 Product Description

Faucets and the faucet accessories work together to control the flow of water delivered to the end user. The faucet tap mechanism controls the amount of water entering the faucet from the building's main water supply whereas the faucet accessory controls the flow rate of water that is discharged from the faucet. Figure 3.1 and Figure 3.2 illustrate the relationship between faucet tap mechanism and faucet accessory for standard lavatory and kitchen faucets.

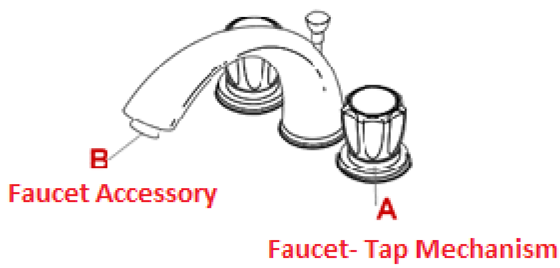


Figure 3.1 Basic Lavatory Faucet Diagram: A) Faucet Tap Mechanism which controls the main water flow and B) Faucet Accessory for further restriction of water flow

Source: Delta Faucet, 2013.

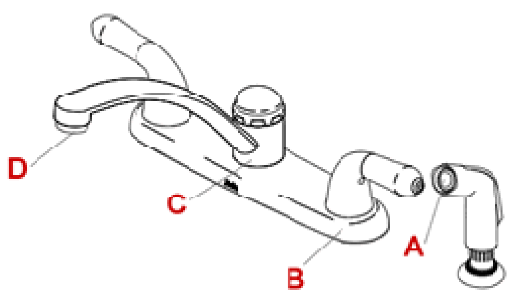


Figure 3.2 Basic Kitchen Faucet Diagram: A) Sprayer, B) Faucet Tap Mechanism which controls the main water flow, C) Stem and D) Faucet Accessory for further restriction of water flow

Source: Delta Faucet, 2013.

Faucet accessories are typically the primary flow control mechanisms. There are two categories of faucet accessories: restricting devices and regulating devices. A restricting device regulates flow by physically narrowing the opening through which water exits the faucet. A regulating device, or pressure compensating device, adapts the size of the opening based on fluctuations in water pressure to maintain a constant flow rate. Common faucet accessories include aerators, laminar flow devices, and spray devices. Each of these accessories is described in more detail in Figure 3.3.

	**Aerators** — air is added to the water to produce softer feeling water that offers the sensation of a stronger flow.
	**Laminar flow devices** — water is forced through a small opening creating a more uniform flow.
	**Spray Devices** — similar to a laminar flow device, water is forced through several small openings creating several parallel water streams providing full coverage of wash area.

Figure 3.3 Classifications of faucet restricting and regulating devices
Source: Neoperl 2013

In addition to the abovementioned faucet accessories, dual-flow devices are another mechanism for restricting and/or regulating water flow. Some low flow faucets (particularly for kitchen use) have the capability of increasing the flow rate for a short period of time to allow pots, basins and other receptacles to be filled more quickly. This dual-flow option is one approach by manufacturers in response to consumer desires for a low flow kitchen fixture that will not come at the expense of longer filling times.

4 Manufacturing and Market Channel Overview

Faucets and faucet accessories are distributed through four primary outlets:

1. Direct sales (i.e., manufacturers sell directly to homebuilders or other volume purchasers);
2. Retail sales;
3. Wholesale plumbing suppliers; and
4. Decorator showrooms.

Manufacturers sell directly to entities that can purchase a large volume of products, such as homebuilders, commercial builders, or water utilities. Distributors have a limited (or non-existent) role in direct manufacturer to installer sales, so the distributor mark-ups are very minimal or eliminated completely. The unit price of units sold through direct sales can be 20 to 50 percent lower than typical retail prices (D&R International 2005).

Retail sales are common for do-it-yourself remodels. Large retailers such as Lowes, Home Depot, and Sears process a majority of the retail sales. These large retailers have a significant influence on which products reach the mainstream retail market. Retailers cannot stock a wide variety of models due, in part, to limited shelf space. The models that are stocked have a distinct advantage over models that are not stocked. Also noteworthy is that water efficiency is not the only factor that purchasers for retail stores consider when making decisions about which models to stock. Price, performance, and appearance are tremendously important. The manner in which unique products are marketed to retail store customers, including how the product is displayed and how it is advertised, impacts the quantity of sales. Often, products are marketed based on price, not water efficiency. Provided water efficiency is not the most important factor in purchasing decisions, the existing labeling requirements that are proposed to remain unchanged are important to educating both retailers and vendors about the relative water efficiency performance of products available on the market.

Some manufactures have localized distribution channels that utilize wholesale distributors to deliver a tailored distribution strategy for different regions. Wholesale distributors may work with builders, water utilities, or retail stores. The wholesaler distribution model is most common for smaller manufacturers that offer specialized products, including premium efficiency faucets and faucet accessories. Sales representatives from the wholesaler can offer personalized messaging to interested customers. Wholesalers tend to target markets with high sales or markets that have an appetite for the specialty products they carry.

Another distribution channel is through showrooms. Manufacturers that offer high-efficiency products may target green building showrooms or choose to market their products at green building trade shows.

5 Water & Energy Usage

5.1 Test Methods

5.1.1 Current Test Methods

Current Title 20 and federal efficiency standards require faucets to be tested and labeled according to procedures described in American Society of Mechanical Engineers / American National Standards Institute (ASME/ANSI) Standard A112.18.1–1996–Plumbing Fixture Fittings. The current version of this standard is ASME A112.18.1–2011 / Canadian Standards Association (CSA) B125.1-11 – Plumbing Supply Fittings. Currently, DOE has a rulemaking in progress to update the federal test procedure for faucets to A112.18.1–2011 / CSA B125.1-11 (77 Fed. Reg. 104, 30 May 2012; 78 Fed. Reg.67, 8 April 2013).

5.1.2 Proposed Test Methods

The proposed test method to verify water use from faucets is ASME A112.18.1–2011/ CSA B125.1-11 – Plumbing Supply Fittings.

5.2 Water & Energy Use per Unit for Non-Qualifying Products

Table 5.1 presents the water and energy use for non-qualifying products. Non-qualifying products are products that do not meet the proposed standard described in Section 11 of this report.

The methodology used to calculate these estimates is presented in the following sections.

Table 5.1 Average Water & Energy Use for Non-Qualifying Products

Product Class	Unit Water Consumption (gal/yr)	Natural Gas Consumption from Water Heating (therms/yr)	Electricity Consumption from Water Heating (kWh/yr)	Embedded Electricity Consumption (kWh/yr)
Lavatory Faucets	2,328	13	172	23
Kitchen Faucets	13,030	53	961	131

Source: CASE Team analysis 2013

5.2.1 Lavatory Faucets

Water Use

To calculate the amount of water non-qualifying product use in California, the CASE Team determined how often lavatory faucets are used on a daily basis and how much water use is associated with each faucet use event. The number of daily household lavatory events was estimated assuming that a lavatory faucet was used every time a toilet was flushed and every time there was a shower event, as outlined in Equation 5.1. This is a conservative assumption of lavatory faucet use as people also use lavatory faucets for washing their face, shaving, and brushing their teeth, among other uses.

Equation 5.1 Lavatory Faucet Events per Household per Day

$$\begin{aligned}&Lavatory\ faucet\ events\ per\ houshold\ per\ day\\&\qquad = toilet\ flushes\ per\ day\ + shower\ events\ per\ day\end{aligned}$$

The number of events per faucet per day was derived by dividing the total faucet events per household by the number of faucets per household (Equation 5.2). Estimates of the number of faucets per household were derived using installed stock estimates, which are discussed in Section 6.1 of this report. The CASE Team used construction forecasts developed for 2013 Building Energy Efficiency Standards rulemaking to estimates of the total number of houses in California (CEC 2012).

Equation 5.2 Events per Faucet per Day

$$Events\ per\ faucet\ per\ day = Faucet\ events\ per\ houshold\ per\ day\ \div \#\ \boldsymbol{faucets\ per\ household}$$

Where: $\#\ \boldsymbol{faucets\ per\ household} = \frac{total\ installed\ faucet\ stock\ (2010)}{total\ number\ of\ homes\ in\ California\ (2010)}$

Next, daily water use per non-qualifying faucet was calculated using the assumption that average duration of a faucet event is 37 seconds and the actual flow rate of non-qualifying products (Equation 5.3).

The *rated* flow rate of non-qualifying products is the weighted average flow rate of all non-qualifying products, and was derived using information about market share of non-qualifying products; 53 percent of non-qualifying products are rated at 2.2 gpm and 43 percent are rated at 1.5 gpm (see Section 6.1).

Equation 5.3 Daily Water Use per Non-Qualifying Faucet

$$Daily\ water\ use\ per\ faucet = events\ per\ faucet\ per\ day \times \frac{37\ sec}{60\ sec/min} \times nonqualifying\ flow\ rate$$

Where: $\boldsymbol{nonqualifying\ flow\ rate} = derating\ factor\ \times \sum_n rated\ flow\ rate\ \times market\ share$

Rated flows are measured at 60 psi. *Actual* flow rates are lower than rated flow rates because people do not always run their faucets at the highest flow rates (i.e., all the way on). In addition, the water pressure in buildings can vary significantly and is often below 60 ps. If the building's water pressure is less than 60 psi it is likely that the faucet flow rate in faucets will be lower than the rated flow rate, particularly if the faucet does not have a pressure-compensating aerator. Finally, faucet aerators are rated when they are not attached to a faucet. Actual flow rate will be lower than the rated flow rate because the faucet itself acts as a restriction device and reduces flow rates. To Derating factors are used to adjust for this discrepancy in rated versus actual (realized) flow rates.

Annual water use from non-qualifying products was calculated by multiplying daily usage by 365 days per year (Equation 5.4).

Equation 5.4 Annual Water Use for Non-Qualifying Products Per Faucet

$$Annual\ water\ use\ per\ faucet = Daily\ water\ use\ per\ faucet \times 365\ \frac{days}{year}$$

Table 5.2 presents the assumptions used to calculate annual per unit water use for lavatory faucets.

Table 5.2 Assumptions Used to Calculate Annual per Unit Water Use

Metric	Value	Source
Number of Lavatory Faucet Events per House per Day [a]	13.8	CASE Team analysis
Flushes per person per day	4.76	Aquacraft 2011
People per household	2.91	U.S. Census Bureau 2013
Number of Shower Events per House per Day	1.97	Aquacraft 2011
Number of Lavatory Faucets per House [b]	2.01	CASE Team analysis
Installed Lavatory Faucets (2010)	25,942,749	See Section 6.x.x
Number of Homes (2010)	12,885,684	See Section 6.x.x
Average Duration of Faucet Event	37 seconds	Aquacraft 2011
Flow rate derating factor for non-qualifying products	0.67	Aquacraft 2000
Market share of non-qualifying products		
2.2 gpm	57%	See Section 6.x.x
1.5 gpm	43%	See Section 6.x.x
Weighted average flow rate (actual) of non-qualifying product	1.3 gpm	CASE Team analysis

a. flushes per person per day x 2.91 people per household
b. Installed faucets ÷ total houses
c. Derating factor x {(2.2 gpf x 57%) + (1.5 gpf x 43%)}

Annual Energy Use per Faucet for Heating Water

Energy is required to heat hot water used in faucets. For this analysis it was assumed that on average, water would be heated 59 °F from 65 °F to 124 °F. The assumption about cold water inlet temperature is rooted in a recent CASE analysis that supported a 2013 revision to the California Building Code (Title 24) (CA IOUs 2011). The assumption about hot water supply temperature is based on the assumptions used in the 2013 California Building Code Residential Alternative Calculation Method calculations (CEC 2013c).

The CASE Team used standard thermodynamics calculations to determine the amount of energy required to heat a gallon of water (see Equation 5.5).

Equation 5.5 Energy Required to Heat a Gallon of Water

$$Q = cm\Delta T$$

Where: Q = energy required to heat water (BTU/gal)
c = specific heat of water (BTU/lb-°F
m = mass of water (lb/gal)
ΔT = temperature change (°F)

Next, the CASE Team accounted for losses due to water heater inefficiencies by dividing by water heater energy factors (Equation 5.6). The water heater energy factors used in this analysis are the national shipment weighted average energy factors as calculated by DOE for the National Impact Analysis for Energy Efficiency Standards for Pool Heaters, Direct Heating Equipment and Water Heaters (DOE 2011). This assumes that, on average, California's water heaters are the same efficiency as water heaters across the nation. Water heaters in California are likely more efficient than water heaters in the nation as a whole.

Standard energy conversion factors were used to convert energy use in BTU to electricity or natural gas need to heat a gallon of water.

Equation 5.6 Conversion of Energy Use to Electricity/Natural Gas to Heat a Gallon of Water

$$\frac{therms}{gallon} or \frac{kWh}{gallon} = Q \div Water\ Heater\ Energy\ Factor \times Energy\ Conversion\ Factor$$

Finally, the CASE Team arrived at the amount of natural gas or electricity required to heat hot water used in non-qualifying lavatory faucets by multiplying energy required to heat one gallon by the volume of hot water used per faucet per year. It was assumed that 70 percent of water used in lavatory faucets is hot water (Equation 5.7).

Equation 5.7 Annual Energy Used to Heat Water

$$Annual\ energy\ used\ to\ heat\ water = energy\ per\ gallon \times annual\ water\ use\ per\ faucet \times 70\%$$

The assumptions used to calculate per faucet annual electricity and natural gas use for water heating are presented in Table 5.3.

Table 5.3 Assumptions Used to Calculate Annual per Unit Energy Use for Water Heating

Metric	Value	Source
Physical Properties of Water		
Specific Heat of Water at 100°F, 1 atm	0.998 BTU/lb-°F	
Mass of Water at 100°F, 1 atm	8.29 lbs/gal	
Energy Conversion Factors		
	3,412 BTU/kWh	U.S. EIA
	100,000 BTU/therm	U.S. EIA
Electric Water Heater Energy Factor	0.97	DOE 2011
Natural Gas Water Heater Energy Factor	0.60	DOE 2011
Temperature Change (ΔT)	59 °F	
Cold water inlet temperature	65 °F	CA IOUs 2011
Hot water supply temperature	124 °F	CEC 2013c
Percent of all Water Use that is Hot Water	50%	EBMUD 2003

The CASE Team recognizes that there is an inverse relationship between flow rate and temperature losses in pipes; as flow rate decreases temperature drop increases. A 2005 Public Interest Energy Research (PIER) Program study evaluated how flow rates impact temperature drop. Researchers measured temperature drop when 135 °F water moves through 100 feet of pipe. They concluded that reducing flow rate from 2.0 gpm to 1.0 gpm can increase temperature losses by 0.5 -3.4 °F. The magnitude of the temperature loss depends on a number of factors including pipe size, pipe material, and insulation level (CEC 2006). In most cases, people will compensate for the temperature losses by adding slightly less cold water at the tap. However, in some cases users may adjust the water heater temperature settings upward. There is a measurable energy penalty if the temperature setting on the water heater is adjusted upward.

Overall, the energy penalty due to temperature drop is small relative to the energy savings from reduced hot water use that are achieved when using low-flow faucets. The analysis presented in this report does not account for temperature drop.

Annual Embedded Electricity Use per Faucet

Energy is required to supply, convey, make water potable, deliver, collect, and treat wastewater. For this analysis, it was assumed that every million gallons of water used for an indoor application in California is attributable to 10,045 kWh of electricity use. 12Appendix A: describes the methodology for calculating the embedded energy value.

5.2.2 Kitchen Faucets

Annual Water Use per Faucet

The methodology to calculate annual water used from kitchen faucets is the same as the methodology described above for lavatory faucets, with the following two modifications.

To calculate the number of kitchen faucet events per household per day, the CASE Team subtracted the lavatory faucet events from estimates of total faucet events per household per day (Equation 5.8).

Equation 5.8 Total Faucet Events per Household per Day

$$\begin{aligned} &Kitchen\ faucet\ events\ per\ household\ per\ day \\ &\quad = total\ faucet\ events\ - lavatory\ faucet\ events \end{aligned}$$

One of the primary kitchen faucet uses is filling pots and basins. Reducing the faucet flow rate will reduce water used washing and rinsing dishes, but it will not reduce water used to fill basins. The CASE Team assumed that 3 gallons of water per faucet per day goes towards filling basins.

Table 5.4 presents the assumptions used to calculate annual per unit water use for lavatory faucets.

Table 5.4 Assumptions Used to Calculate Annual per Unit Water Use

Metric	Value	Source
Number of Kitchen Faucet Events per Household per Day [a]	41.6	CASE Team analysis
Faucet Events per Household per Day	57.4	Aquacraft 2011
Lavatory Faucet Events per Household per Day	13.8	See Section 5.2.1
Number of Kitchen Faucets per House [b]	1.04	CASE Team analysis
Installed Kitchen Faucets (2010)	13,357,895	See Section 6.1.1
Number of Homes (2010)	12,885,684	See Section 6.1.1
Average Duration of Faucet Event	37 seconds	Aquacraft 2011
Daily water used to fill pots and basins	3 gal/day-faucet	assumption
Flow rate derating factor for non-qualifying products	0.67	Aquacraft 2000
Market share of non-qualifying products		
2.2 gpm	77%	See Section 6.1.2
1.81 – 2.19 gpm	23%	See Section 6.1.2
Average flow rate (actual) of non-qualifying product	1.4 gpm	CASE Team analysis

a. 57.4 events total – 13.8 lavatory faucet events

b. Installed faucets ÷ total houses

Annual Energy Use per Faucet for Heating Water

The methodology used to calculate energy used to heat water used in kitchen faucets is the same as the methodology described above for lavatory faucets. The assumptions for kitchen faucets are the same as the assumptions used for lavatory faucets, as presented in Table 5.3.

Annual Embedded Electricity Use per Faucet

The methodology used to calculate energy used to heat water used in kitchen faucets is the same as the methodology described above for lavatory faucets.

5.3 Efficiency Measures

Efficiency for a faucet or faucet accessory is achieved by lowering the flow rate through the addition of a restricting or regulating flow control device. The capability of achieving high efficiency is a matter of increasing the restriction or regulation of the flow control mechanism. Since faucet accessories are the main method for flow control in faucet, the ease in which a faucet accessory can reach efficiency makes this ability the same for the faucet as a whole.

The proposed Title 20 code change presented in this report would revise the water efficiency standards for residential lavatory and kitchen faucets. The proposed standard for lavatory faucets would be a maximum flow rate of 1.0 gallon per minute (gpm) tested at a water pressure of 60 pounds per square inch (psi) and a minimum flow rate of 0.5 gpm at 20 psi. The proposed standard for kitchen faucets is a maximum flow rate of 1.8 gpm with an allowance for dual flow accessories that temporarily increase the flow rate to 2.2 gpm.

5.4 Water & Energy Use per Unit for Qualifying Products

Table 5.5 presents the water and energy use for qualifying products. Qualifying products are products that do meet the proposed standard described in Section 11 of this report.

The methodology used to calculate these estimates is described in the following sections.

Table 5.5 Average Water & Energy Use for Qualifying Products

Product Class	**Unit Water Consumption (gal/yr)**	**Natural Gas Consumption from Water Heating (therms/yr)**	**Electricity Consumption from Water Heating (kWh/yr)**	**Embedded Electricity Consumption (kWh/yr)**
Lavatory Faucets	1,319	5	97	13
Kitchen Faucets	11,944	49	881	120

Source: CASE Team analysis 2013

5.4.1 Lavatory Faucets

The per unit water and energy use for the qualifying products was calculated in the same manner as the non-qualifying products' water and energy use with the exception that qualifying lavatory faucets are rated at 1.0 gpm and the derating factor for qualifying products is 0.75. Each qualifying lavatory faucet is expected to consume 1,319 gallons per year with an associated embedded energy use of 13 kWh per year. If the house has a natural gas water heater, 5 therms of natural gas will be used to heat water used in the lavatory faucet. If the house has an electric water heater, 97 kWh of electricity will be used to heat water used in the lavatory faucet.

5.4.2 Kitchen Faucets

The per unit water and energy use for the qualifying products was calculated in the same manner as the non-qualifying products' water and energy use with the exception that qualifying kitchen faucets are rated at 1.8 gpm. The derating factor for qualifying kitchen faucets is the same as non-qualifying products (i.e., derating factor of 0.67). Each qualifying kitchen faucet is expected to consume 11,944 gallons per year with an associated embedded energy use of 120 kWh per year. If the house has a natural gas water heater, 49 therms of natural gas will be used to heat water used in the lavatory faucet. If the house has an electric water heater, 881 kWh of electricity will be used to heat water used in the lavatory faucet.

6 Market Saturation & Sales

6.1 Current Market Situation

6.1.1 Total Stock and Shipments

Table 6.1 presents the estimated existing stock and annual sales of lavatory and kitchen faucets. It is estimated that there are approximately 26.8 million lavatory faucets and 13.8 million kitchen faucets installed in residential buildings in California. Annual sales of lavatory faucets are projected to be in the range of 3.0 and 3.7 million per year between 2015 and 2030. Annual sales of kitchen faucets are projected to be in the range of 1.5 and 1.9 million per year between 2015 and 2030. These projections include both qualifying and non-qualifying products installed in houses with all types of water heaters.

The sections below explain the methodology used to arrive at the sales and stock projections.

Table 6.1 California Annual Sales and Stock (2013 – 2030)

	Lavatory Faucets		Kitchen Faucets	
Year	Annual Sales	Stock	Annual Sales	Stock
2013	2,976,950	26,815,188	1,526,368	13,792,553
2014	3,011,759	27,115,406	1,543,619	13,941,975
2015	3,047,082	27,420,444	1,561,115	14,093,718
2016	3,083,054	27,730,453	1,578,925	14,247,857
2017	3,119,596	28,045,499	1,597,006	14,404,421
2018	3,156,753	28,365,684	1,615,386	14,563,460
2019	3,194,570	28,691,140	1,634,083	14,725,039
2020	3,232,987	29,021,934	1,653,068	14,889,188
2021	3,271,944	29,358,071	1,672,315	15,055,912
2022	3,311,532	29,699,639	1,691,866	15,225,253
2023	3,351,762	30,046,728	1,711,725	15,397,252
2024	3,392,644	30,399,429	1,731,896	15,571,953
2025	3,434,188	30,757,834	1,752,386	15,749,400
2026	3,476,406	31,122,036	1,773,200	15,929,636
2027	3,519,309	31,492,132	1,794,342	16,112,707
2028	3,562,908	31,868,219	1,815,817	16,298,658
2029	3,607,215	32,250,395	1,837,632	16,487,537
2030	3,652,241	32,638,760	1,859,792	16,679,390

This estimate was derived using housing construction forecasts that were developed by the CEC for use in the 2013 Building Energy Efficiency Standards rulemaking (CEC 2012). Assumptions about the number of faucets per household were derived from a 2002 study published by East Bay Municipal Utility District (EBMUD) that surveyed installed faucets in EBMUD service territory. The CASE Team assumed that the faucet prevalence in EBMUD territory is a reasonable approximate for faucet prevalence in the state as a whole. It is assumed that there are 3.8 faucets per single-family household; 63 percent of these faucets are lavatory faucets, 28 percent are kitchen faucets, and the remaining are other faucets including utility faucets. It is assumed that there are 2.3 faucets per multi-family residence; 1 kitchen faucet per household and 1.3 lavatory faucets per home (EBMUD 2002). The average number of lavatory and kitchen faucets per housing unit is assumed to remain constant throughout the forecast period (2015 – 2030).

Total annual sales include faucets purchased for installation in newly constructed buildings plus faucets purchased to replace existing products. It is assumed that 10 percent of existing faucets are replaced each year.

The number of faucets in buildings with natural gas or electric water heating was derived using data from the CEC's 2009 California Statewide Residential Appliance Saturation Study (RASS) (CEC 2009). The study found that 92.7 percent of homes have water heating. Of these homes, 87.9 percent have natural gas water heaters, 7.6 percent have electric water heaters, 4.3 percent have propane heaters, and the remaining households use propane, solar or another source for water heating. The cost and energy analysis presented in this report includes energy and cost savings from homes with natural gas or electric water heaters.

6.1.2 Market Share of High Efficiency Options

In 2001, EBMUD conducted a study to evaluate the efficiency of products installed in residential buildings in its service territory. Researchers measured the flow rates of faucets and found that 55.5 percent of faucets in single-family homes and 10.7 percent of faucets in multi-family buildings used 2.2 gpm or less (EBMUD 2002). This data suggests that there are many inefficient faucets in use today. However, old faucets are increasingly being replaced with more efficient products. WaterSense has proven to be a driving force in pushing the market towards high-efficiency lavatory faucets. The WaterSense High-Efficiency Lavatory Faucet Specification was released in 2007. It is now estimated that as many as 50 percent of lavatory faucets sold in the United States are now WaterSense Labeled products.

CEC's Appliance Efficiency Database lists models available for sale in the state. While the database does not indicate shipments of each product, it does provide a rough approximation of the type of products being sold in the state. As of July 2013, the database lists 3,324 lavatory faucets and 347 lavatory faucet accessories and 2,722 kitchen faucets and 193 kitchen faucet replacement aerators.[3] Tables 6.2 and 6.3 present a summary of the number of models available by rated flow rate (CEC 2013a). Overall, the data suggests that it is technically feasible to meet the proposed standards and many manufacturers are already offering qualifying products for sale in the California market.

As can be seen in Table 6.2, approximately 3 percent of lavatory faucets and 12 percent of faucet accessories meet the proposed standard for maximum flow rate, respectively. Though these are relatively small percentages, they do demonstrate that higher efficiency products currently exist in

[3] There are 86 replacement faucet aerators not specified as kitchen or lavatory in the CEC Appliance Efficiency Database (2013).

the market. Qualifying faucets are available from 5 manufacturers representing 7 brand names, and qualifying replacement aerators are available from 3 manufacturers representing 3 brand names.

Table 6.3 indicates that approximately 22 percent of kitchen faucets and approximately 25 percent of accessories meet the proposed 1.8 gpm standard for maximum flow rate, respectively. These are fairly significant percentages of the existing market for kitchen faucets and aerators, and thus, demonstrate that higher efficiency products are available to consumers. Qualifying kitchen faucets are available from 19 manufacturers representing 96 brand names, and qualifying kitchen replacement aerators are available from 3 manufacturers representing 3 brand names.

Table 6.2 Summary of Lavatory Faucets and Accessories in CEC Database

Rated Flow Rate (GPM)		Count			Percent		
		Kitchen Faucets	Kitchen Faucet Aerators	Total	Kitchen Faucets	Kitchen Faucet Aerators	Total
Non-qualifying	2.2	980	34	1,014	32%	10%	30%
	1.51 - 2.19	829	154	983	27%	44%	29%
	1.01 - 1.5	1,154	76	1,230	38%	22%	36%
Qualifying	0.5 - 1	10	32	42	0%	9%	1%
	≤ 0.5	78	51	129	3%	15%	4%
	TOTAL	**3,051**	**347**	**3,398**	**100%**	**100%**	**100%**

Table 6.3 Summary of Kitchen Faucets and Accessories in CEC Database

Rated Flow Rate (GPM)		Count			Percent		
		Kitchen Faucets	Kitchen Faucet Aerators	Total	Kitchen Faucets	Kitchen Faucet Aerators	Total
Non-qualifying	2.2	1,634	40	1,674	60%	21%	57%
	2.1 -2.19	51	17	68	2%	9%	2%
	1.81 -2.0	433	87	520	16%	45%	18%
Qualifying	1.51- 1.8	165	22	187	6%	11%	6%
	1.01 - 1.5	411	16	427	15%	8%	15%
	≤ 1.0	28	11	39	1%	6%	1%
	TOTAL	**2,722**	**193**	**2,915**	**100%**	**100%**	**100%**

6.2 Future Market Adoption of High Efficiency Options

The market share of high-efficiency residential faucets and faucet accessories is expected to increase over time. The CASE Team estimates that the market share of products that meet the proposed standards will increase from 5 percent (lavatory) and 22 percent (kitchen) in 2013 to 30 percent (lavatory) and 50 percent (kitchen) by 2030. The savings values presented in this report do not account for naturally occurring market adoption. The estimates assume the market share of qualifying products will remain constant at current (2013) levels through the evaluation period.

7 Savings Potential

7.1 Statewide California Water and Energy Savings

Statewide water and energy consumption is based on multiplying stock against weighted per-product water and energy consumption. Water and energy savings are calculated assuming a market shift from the weighted average of non-qualifying and qualifying products to all qualifying products, beginning in the effective year, 2015.

The proposed revisions to the residential faucet standards will bring Title 20 standards in closer alignment with existing standards in CalGreen, the California Plumbing Code, and WaterSense specifications. The specific code change proposal is described in detail in Section 10 of this report. The statewide energy and water savings associated with the proposed changes are presented below.

Table 7.1 presents the estimated water energy use if the proposed changes are not adopted and the Title 20 standards remain unchanged (Non-standards Case). Table 7.2 present the estimated water and energy use if the proposed standard is adopted (Standards Case). Table 7.3 presents the estimated water and energy savings if the proposed standards are adopted.

The annual sales values represent the water or energy use (or savings) associated with products sold during a given year. The stock values represent the water or energy use (or savings) associated with all products that are *installed* and operational during a given year.

The statewide savings estimates were calculated by applying the unit water and energy savings, which are presented in Section 7 of this report, to the statewide stock and sales forecast presented in Section 6 of the report. The statewide savings estimates presented below does not include propane savings from 4.3 percent of water heaters in the state that use propane.

Table 7.1 California Statewide Non-Standards Case Water & Energy Use – After Effective Date

Product Class	Annual Sales					Stock				
	Water Use (million gal/yr)	Natural Gas Use (million therms/yr)	Electricity Use (GWh/yr)	Embedded Electricity Use (GWh/yr)	Electricity Demand (MW)	Water Use (million gal/yr)	Natural Gas Use (million therms/yr)	Electricity Use (GWh/yr)	Embedded Electricity Use (GWh/yr)	Electricity Demand (MW)
2015 (first year standard is in effect)										
Lavatory Faucets	6,951	23	36	70	8.3	68,145	226	356	685	81.2
Kitchen Faucets	19,966	66	104	201	23.8	195,878	649	1,023	1,968	233.5
Total	**26,916**	**89**	**141**	**270**	**32.1**	**264,023**	**875**	**1,378**	**2,652**	**314.7**
2024 (year stock turns over)										
Lavatory Faucets	7,739	26	40	78	9.2	73,363	243	383	737	87.4
Kitchen Faucets	22,150	73	116	222	26.4	210,351	697	1,098	2,113	250.7
Total	**29,889**	**99**	**156**	**300**	**35.6**	**283,714**	**941**	**1,481**	**2,850**	**338.2**

Source: CASE Team analysis 2013

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002). Demand savings were calculated based on electricity savings from heating water; demand savings from embedded electricity are not included in the analysis.

Table 7.2 California Statewide Standards Case Water & Energy Use – After Effective Date[a]

Product Class	Annual Sales: Water Use (million gal/yr)	Annual Sales: Natural Gas Use (million therms/yr)	Annual Sales: Electricity Use (GWh/yr)	Annual Sales: Embedded Electricity Use (GWh/yr)	Electricity Demand (MW)	Stock: Water Use (million gal/yr)	Stock: Natural Gas Use (million therms/yr)	Stock: Electricity Use (GWh/yr)	Stock: Embedded Electricity Use (GWh/yr)	Electricity Demand (MW)
2015 (first year standard is in effect)										
Lavatory Faucets	4,018	13	21	40	4.8	65,212	216	340	655	77.7
Kitchen Faucets	18,646	62	97	187	22.2	194,558	645	1,016	1,954	231.9
Total	**22,664**	**75**	**118**	**228**	**27.0**	**259,770**	**861**	**1,356**	**2,609**	**309.6**
2024 (year stock turns over)										
Lavatory Faucets	4,474	15	23	45	5.3	42,410	141	221	426	50.5
Kitchen Faucets	20,685	69	108	208	24.7	196,444	651	1,026	1,973	234.1
Total	**25,159**	**83**	**131**	**253**	30.0	**238,854**	**792**	**1,247**	**2,399**	**284.7**

Source: CASE Team analysis 2013

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002). Demand savings were calculated based on electricity savings from heating water; demand savings from embedded electricity are not included in the analysis.

Table 7.3 California Statewide Water & Energy Savings for Standards Case – After Effective Date[a]

	Annual Sales					Stock				
Product Class	Water Savings (million gal/yr)	Natural Gas Savings (million therms/yr)	Electricity Savings (GWh/yr)	Embedded Electricity Savings (GWh/yr)	Electricity Demand Savings (MW)	Water Savings (million gal/yr)	Natural Gas Savings (million therms/yr)	Electricity Savings (GWh/yr)	Embedded Electricity Savings (GWh/yr)	Electricity Demand Savings (MW)
2015 (first year standard is in effect)										
Lavatory Faucets	2,933	10	15	29	3.5	2,933	10	15	29	3.5
Kitchen Faucets	1,320	4	7	13	1.6	1,320	4	7	13	1.6
Total	**4,253**	**14**	**22**	**43**	**5.1**	**4,253**	**14**	**22**	**43**	**5.1**
2024 (year stock turns over)										
Lavatory Faucets	3,265	11	17	33	3.9	30,953	103	162	311	36.9
Kitchen Faucets	1,464	5	8	15	1.7	13,907	46	73	140	16.6
Total	**4,730**	**16**	**25**	**48**	**5.6**	**44,860**	**149**	**234**	**451**	**53.5**

Source: CASE Team analysis 2013

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002). Demand savings were calculated based on electricity savings from heating water; demand savings from embedded electricity are not included in the analysis.

7.2 State or Local Government Costs and Savings

There are no known additional costs to state or local governments from the implementation of the standards proposal, given the CEC's existing authority for establishing appliance standards and staffing to administer the process. Energy savings are expected for local and state governments from the purchase of more efficient products as a result of the proposed standard, with the savings amount dependent on the volume of products purchased.

8 Economic Analysis

8.1 Incremental Cost

As mentioned, faucet accessories dictate flow rate. To achieve the desired flow rate, manufacturers can modify the accessory without changing the faucet design. Since the cost is dictated by the accessory, incremental cost was analyzed based on the cost of the faucet accessory rather than the entire faucet with accessory.

The CASE Team found very little price difference between higher and lower efficiency faucets and faucet accessories. For example, the NEOPERL 2012 Wholesale catalog indicates no cost difference between non-qualifying (2.2 gpm and 1.5 gpm) and qualifying faucet accessories (1.0 gpm for lavatory and 1.5 gpm for kitchen). Since NEOPERL manufactures the vast majority of lavatory faucet accessories used within this industry, the CASE Team assumes a very small incremental cost between a non-qualifying and qualifying unit.

8.2 Design Life

The design life of a residential faucet accessory is 10 years. The faucet itself has longer a longer life—the design life of lavatory and kitchen faucets is 20+ years and 15 years, respectively (NAHB 2007) — it is assumed that the faucet accessory may be replaced before the faucet is replaced. Additionally, Niagara Conservation®, one manufacturer of high efficiency water products, includes a 10 year Limited Warranty for Aerators obtained through wholesale, municipalities, utilities, or other commercial channels (Niagara Conservation 2013). This warranty further supports the use of 10 years as an assumed 10-year design life for faucet accessories.

8.3 Lifecycle Cost / Net Benefit

The lifecycle cost and net benefits of the proposed standards are presented in Table 8.1and Table 8.2. Since the incremental cost is negligible, adoption of the standard is not expected to result in any economic burden to customers. It is estimated that over the lifetime of the product, consumers will save money through reduced water and associated water heating costs.

Table 8.1 Lifecycle Costs and Benefits per Unit for Qualifying Products[a]

Product Class	Design Life (years)	Lifecycle Costs per Unit (Present Value $) Incremental Cost	Add'l Costs	Total PV Costs	Lifecycle Benefits per Unit (Present Value $) Water Savings[a]	Energy Savings	Total PV Benefits
Lavatory Faucets	10	$0	$0	$0	$83	$169	$252
Kitchen Faucets	10	$0	$0	$0	$90	$182	$272
TOTAL		**$0**	**$0**	**$0**	**$173**	**$351**	**$524**

PV = Present Value

[a] Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2012).

Table 8.2 Lifecycle Cost Benefit Ratio for Qualifying Products and Net Present Values with Standards Case[d]

Product Class	Lifecycle Benefit / Cost Ratio[a]	Net Present Value ($)[b,c] Per Unit	For First Year Sales	Stock Turnover [d]
Lavatory Faucets	n/a	$252	$733	$8,151
Kitchen Faucets	n/a	$272	$330	$3,662
TOTAL		**$524**	**$1,063**	**$11,814**

[a] Total present value benefits divided by total present value costs.

[b] Positive value indicates a reduced total cost of ownership over the life of the appliance.

[c] Cost savings will be realized through lower electricity, gas, and water bills. Average annual electricity, gas and water rates were used, starting in the effective year (see Appendix B for more details). It should be noted that while the proposed standard is cost-effective, it may be more cost-effective if using alternative rate structures. For example, marginal utility rates may more accurately reflect what customers save on utility bills as result of the standard.

[d] Stock Turnover NPV is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year, i.e., the NPV of "turning over" the whole stock of less efficient products that were in use at the effective date to more efficient products, plus any additional non-replacement units due to market growth, if applicable. For example, for a standard effective in 2015 applying to a product with a 5 year design life, the NPV of the products purchased in the 5th year (2019) includes lifecycle cost and benefits through 2024, and therefore, so does the Stock Turnover NPV.

9 Acceptance Issues

9.1 Infrastructure Issues

9.1.1 User Satisfaction

Three studies conducted by Aquacraft, Inc. Water Engineering Management suggest that users are satisfied with low-flow faucets (Aquacraft 2000, Aquacraft 2003, Aquacraft 2004). In both Seattle, Washington and the East Bay Municipal Utility District (EBMUD) service territory in the Bay Area, users expressed a high level of user satisfaction with a 1.5 gpm pressure compensating aerator. These studies reveal that 58 percent of participants in Seattle and 80 percent of participants in EDMUD felt the high-efficiency aerators performed the same or better than their old fixtures. In Tampa, Florida 1.0 gpm at 60 psi were installed, and 89 percent of study participants felt the high-efficiency aerators performed the same or better than their old fixtures. Based on this evidence that users are more satisfied with faucets that consume less water, the CASE Team is not expecting significant dissent from consumers regarding an updated California standard.

In terms of kitchen faucet accessories, data on end use is not readily available due to the difficulty in determining the variation in kitchen tasks, including whether people pre-rinse dishes prior to loading the dishwasher. However, preliminary research on customer satisfaction regarding dual flow kitchen accessories indicates that end users are generally pleased with the overall functionality of higher efficiency faucets and faucet accessories. For example, Niagara Conservation's 0.5 GPM Low Flow Dual-Thread Faucet Laminar has received positive customer reviews (Amazon.com 2013).

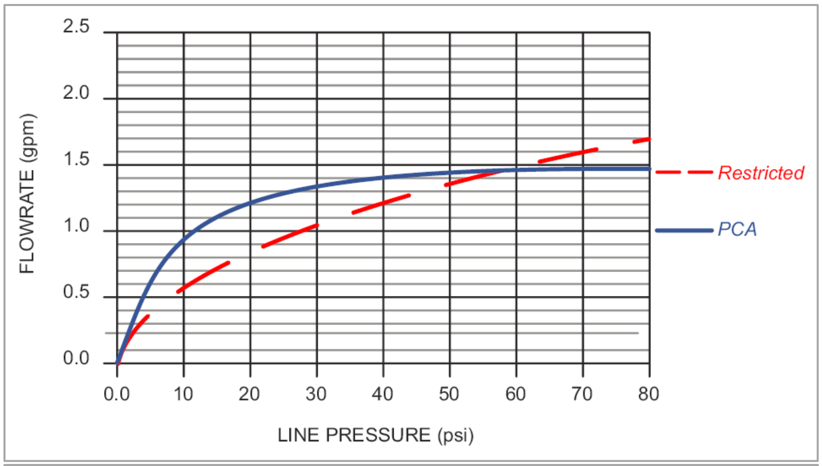
9.1.2 Tampering with Faucet Accessory

Some stakeholders have expressed concern that users can remove the faucet accessory from the faucet thereby negating all potential savings from a faucet standard. While accessories are sometimes removed from faucets, most people do not remove the accessory. Faucet aerators were found in 94 percent of the single-family and multi-family homes that were evaluated during a 2001 EBMUD field survey (EBMUD 2002). The CASE Team recognizes that some accessories will be removed. However, this is viewed as a compliance issue rather than a reason not to pursue a faucet standard. Overall, the standard will result in significant water and energy savings, even if a small percentage of the faucets will not achieve any water or energy savings due to tampering.

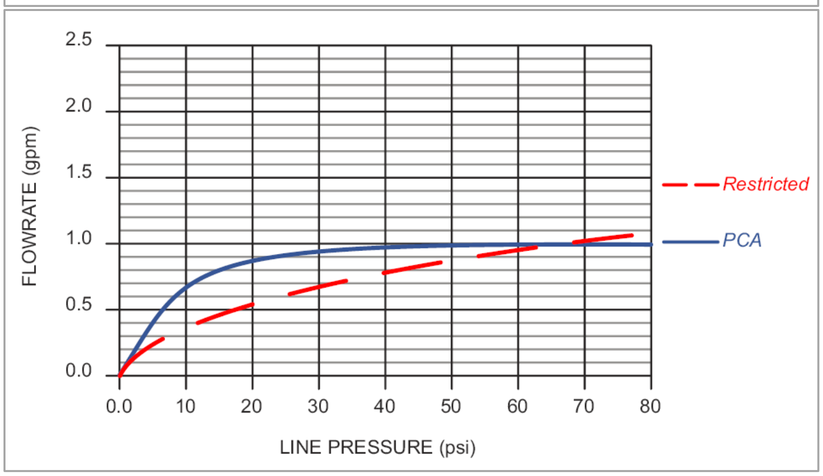
9.1.3 Minimum Flow Rate

The WaterSense High-Efficiency Lavatory Faucet Specification requires faucets to achieve a least 0.8 gpm at 20 psi (WaterSense 2007a). This minimum flow rate requirement helps ensure that faucets will deliver an adequate flow even if a building's water pressure is low (WaterSense 2007c). This safeguard is in place to guarantee that users will be satisfied with WaterSense Labeled faucets. The CASE Team agrees with EPA that that a faucet's utility should be maintained as water efficiency improves. However, it is also important that the minimum performance standard does not inadvertently prevent efficient products that receive high user satisfaction scores from being sold in the state. Establishing a minimum performance standard is difficult because each individual use has different expectations, and the definition of "acceptable" flowrate is not standard across all users. An individual that finds a lower flowrate acceptable should not necessarily be prohibited from purchasing a low flow product. It should also be noted that the water pressure in many buildings is higher than 20 psi. CEC might consider establishing minimum flowrate standards that truly mark the bottom of what would be considered “acceptable” even to the most tolerant individuals.

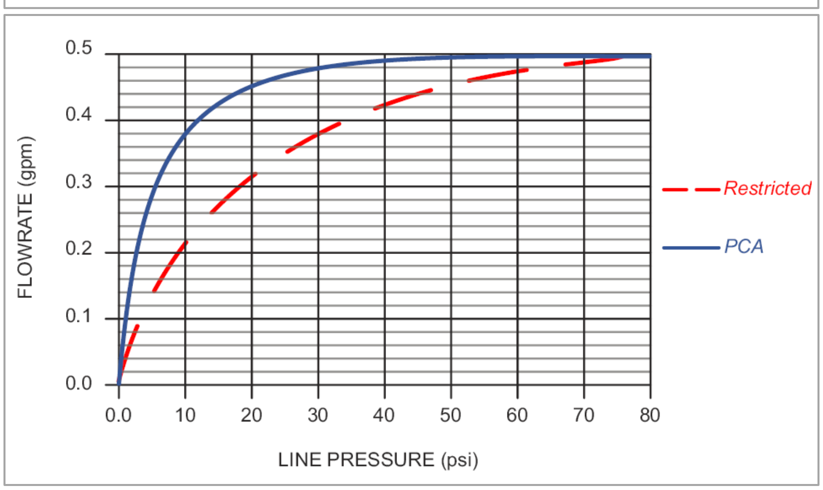
Figure 9.1 presents the flow curves (flow rates at various water pressures) for 1.5 gpm, 1.0 gpm, and 0.5 gpm aerators. The pressure compensating aerator (PCA) rated at 1.5 gpm at 60 psi achieves 1.2 gpm at 20 psi. For comparison, a non-pressure compensating (restricted or orifice) 1.5 gpm aerator can achieve approximately 0.8 gpm at 20 psi. WaterSense adopted the minimum flow rate that the orifice aerator can achieve (0.8 gpm). Following this same logic, the minimum performance standard for a 1.0 gpm aerator would be 0.5 gpm. This CASE proposal recommends a minimum efficiency standard of 0.5 gpm at 20 psi.



(b) 1.5 gpm



(a) 1.0 gpm



(c) 0.5 gpm

Figure 9.1 Flow Curves of 1.5 gpm (a), 1.0 gpm (b), and 0.5 gpm (c) Aerators
Source: Conservation Warehouse International 2013a, 2013b, 2013c

9.2 Existing Standards

9.2.1 Federal Standards

In the 1980s and early 1990s several states, including California, had established water efficiency standards for faucets. Congress used these state-level standards as the basis for nationwide standards that were enacted with the Energy Policy Act of 1992. The federal standards that took effect in 1994 are 2.2 gallons per minute (gpm) when measured at a water pressure of 60 psi for lavatory faucets, lavatory replacement accessories, kitchen faucets, and kitchen replacement accessories and 0.25 gallons per cycle (gal/cycle) for metering faucets.

According to federal law, if ASME revises the standard, DOE must review ASME's action and consider adjusting the federal standards. If ASME does not revise the standard after any period of five consecutive years, DOE must issue a final rule waiving federal preemption, and thereby, allow states to set more stringent state-level standards. ASME did not update the standard for five years, triggering DOE to waive preemption.

On December 22, 2010, the DOE issued a final rule that waived federal preemption for energy conservation standards with respect to any state regulation concerning the water use or water efficiency of faucets, showerheads, water closets, and urinals. This waiver allows states to set their own standards for the relevant plumbing products as long as the state standard is more stringent than the federal standard.[4] Currently, the only state that has set a standard more stringent than the federal standard is Georgia, requiring a maximum flow rate of 1.5 gpm at 60 psi (Georgia SB 370 2010), effective July 1st, 2012. The City of New York has also adopted the same standard and effective date (City of New York 2010), as has the City of Los Angeles with an effective date of September 4, 2009 (City of Los Angeles 2009).

9.2.2 California Standards

Current Title 20 Standards

The current Title 20 standards are consistent with the federal standards, or 2.2 gpm measured at 60 psi for lavatory faucets, kitchen faucets, and replacement accessories.

Requirements Enacted by SB 407 (2009)

In 2009, the California Legislature enacted Senate Bill 407 (Padilla 2009). This bill requires that plumbing fixtures installed in residential and commercial buildings constructed before 1994 be replaced with more efficiency fixtures by 2017 (single-family buildings) or 2019 (multi-family and commercial buildings). Toilets, urinals, showerheads, and faucets are the plumbing fixtures subject to the rules SB 407 established.

CalGreen (Part 11 of Title 24) Standards

The California Green Building Code, which is also known as CALGreen or Part 11 of Title 24, includes mandatory water efficiency standards faucets. CalGreen 2010 requires a 20 percent reduction below the current federal standards for faucets, showerheads, and water closets, which may be achieved either by each individual fitting and fixture or by all fittings and fixtures in a building as a group. Effective January 1, 2014, CalGreen 2013 repeals the performance option allowing averaging of all fixtures and fittings. Additionally, CalGreen 2013 includes the following standards for residential buildings (CalGreen 2012b):

---

[4] 75 CFR 245 (2010-12-22) pg. 80289–80292

- Residential lavatory faucets: maximum flow rate of 1.5 gpm at 60 psi; minimum flow rate of 0.8 gpm at 20 psi.
- Kitchen faucets: maximum flow rate of 1.8 gpm measure at 60 psi; may temporarily increase flow to 2.2 gpm measure at 60 psi, but must default back to max flow rate of 1.8 gpm measure at 60 psi.

California Plumbing Code Standards (Part 5 of Title 24)

The 2010 California Plumbing Code (§ 402.1) includes faucet standards that are consistent with the efficiency levels enacted by the current Title 20 and federal standard (2.2 gpm measured at 60 psi). As a building code, the Plumbing Code establishes standards for products installed during new construction or alterations, but the standards do not apply to all products offered for sale in California. The standards in Title 20 are what dictate the efficiency level for all products that are offered for sale in California.

9.2.3 Other Standards

Other State and Local Standards

Currently, the State of Georgia and the City of New York have enacted standards more stringent than the federal standard. These standards have set the maximum allowable flow rate to 1.5 gpm at 60 psi.

WaterSense

EPA WaterSense defines a high-efficiency lavatory faucet as one with a maximum flow rate of 1.5 gpm at 60 psi, with a minimum flow rate of 0.8 gpm at 20 psi (WaterSense 2007b).

Model Codes

Water efficiency standards already appear in the following "reach" codes:

- 2012 International Green Construction Code: Water Efficiency Provisions
- ASHRAE 189.1-2011: Standards for the Design of High-Performance Green Buildings (Except Low-Rise Residential Buildings)
- International Association of Plumbing and Mechanical Officials (IAPMO) 2012 Green Plumbing and Mechanical Code

9.3 Stakeholder Positions

Faucet manufacturers have expressed a preference that Title 20 standards align with standards in CalGreen, the California Plumbing Code, and the WaterSense Specification. Responses to CEC's Invitation to Participate (ITP) as well as the transcript from the ITP Workshop on May 31, 2013 provide some insight into stakeholder positions.[5]

[5] Documents from CEC's ITP process are available on the CEC's Appliance 2013 Appliance Efficiency Pre-Rulemaking website: http://www.energy.ca.gov/appliances/2013rulemaking/index.html.

10 Environmental Impacts

10.1 Hazardous Materials

There are no known incremental hazardous materials impacts from the efficiency improvements as a result of the proposed standards.

10.2 Air Quality

This proposed measure is estimated to reduce total criteria pollutant emissions in California by 118,000 lbs/year in 2024, after stock turnover, as shown in Table 10.1 due to 686 GWh in reduced end user electricity consumption with an estimated value of $5,653,500. Criteria pollutant emission factors for California electricity generation were calculated per MWh based on California Air Resources Board data of emission rates by power plant type and expected generation mix (CARB 2010). The monetization of these criteria pollutant emission reductions is based on CARB power plant air pollution emission rate data multiplied by the dollar per ton value of these reductions based on Carl Moyer values where available, and San Joaquin Valley UAPCD "BACT" thresholds for sulfur oxides (SOx). These dollar per ton values vary significantly for fine particulates, as discussed in 0 (CARB 2011a; CARB 2013a; San Joaquin Valley UAPCD 2008).

Table 10.1 Estimated California Criteria Pollutant Reduction Benefits (lbs/year) After Stock Turnover

	lbs/year	**Carl Moyer $/ton (2013)**	**Monetization**
ROG	18,899	$17,460	$164,985
Nox	64,457	$17,460	$562,711
Sox	6,775	$18,300	$61,989
PM2.5	27,857	$349,200	$4,863,848
Total	**$118,000**		**$5,653,500**

10.3 Greenhouse Gases

Table 10.2 shows the annual and stock GHG savings by year and the range of the societal benefits as a result of the standard. By stock turnover in 2024, this standard would save 834 metric tons of CO_2e, equal to between $48,00 and $144,000 of societal benefits. The total avoided CO_2e is based on CARB's estimate of 437 MT CO2e/GWh and 53 MT CO2e/million therms) of energy savings from energy efficiency improvements, and includes additional electrical transmission and distribution loses estimated at 7.8 percent (CARB 2008a). The range of societal benefits per year is based on a range of annual dollars per metric ton of CO_2 (in 2013 dollars) sourced from the U.S. Government's Interagency Working Group on Social Cost of Carbon (SCC) (Interagency Working Group 2013). The low end uses the average SCC, while the high end incorporates SCC values which use climate sensitivity values in the 95th percentile, both with 3 percent discount rate. It is important to note that this range can be lower and higher, depending on the approach used, so policy judgments should consider this uncertainty. See Appendix D: for more details regarding this and other approaches.

Table 10.2 Estimated California Statewide Greenhouse Gas Savings and Cost Savings for Standards Case

Product Class	Annual GHG Savings (MT of CO2e/yr)	Stock GHG Savings (MT of CO2e/yr)	Value of Stock GHG Savings - low ($)	Value of Stock GHG Savings - high ($)
2015 (first year standard is in effect)				
Lavatory Faucets	54	54	$2,515	$7,214
Kitchen Faucets	25	25	$1,164	$3,340
Total	**79**	**79**	**$3,679**	**$10,554**
2024 (year stock turns over)				
Lavatory Faucets	61	575	$33,122	$99,365
Kitchen Faucets	27	258	$14,862	$44,585
Total	**88**	**834**	**$47,983**	**$143,950**

11 Recommendations

11.1 Recommended Standards Proposal

The proposed code change would do the following:

- Modify the definition of "replacement aerators" to ensure that all flow restriction and flow regulating devices are covered by the standard.
- Modify the existing maximum flow rate standards for lavatory faucets and replacement lavatory accessories. The proposed maximum flow rate is 1.0 gpm at 60 psi.
- Modify the existing maximum flow rate standard kitchen faucets and replacement kitchen accessories. The proposed maximum flow rate 1.8 gpm, with an allowance for dual flow accessories that temporarily increase the flow rate to 2.2 gpm.
- Establish a new minimum flow rate standard for lavatory faucets, replacement lavatory accessories. The proposed minimum flow rate is 0.5 gpm at 20 psi.
- Revise the test method for lavatory faucets, replacement lavatory accessories, kitchen faucets and replacement kitchen accessories. The recommended test method is ASME Standard A112.18.1-2011/CSA B1.25.1-11.

11.2 Proposed Changes to the Title 20 Code Language

Section 1601. Scope.

(h) Plumbing fittings, which are showerheads, lavatory faucets, kitchen faucets, metering faucets, <u>kitchen</u> replacement accessories, <u>lavatory replacement accessories</u>, wash fountains, tub spout diverters, and commercial pre-rinse spray valves

Section 1602. Definitions

(h) Definitions for Plumbing Fittings.

~~"Kitchen replacement aerator" means an aerator sold as a replacement, separate from the kitchen faucet to which it is intended to be attached.~~

"Kitchen replacement accessory" means all devices designed to regulate water flow including but not limited to: pressure compensating devices, restricting devices, aerator devices, laminar devices, and spray devices that are sold separately from the kitchen faucet to which it is intended to be attached.

~~"Lavatory replacement aerator" means an aerator sold as a replacement, separate from the lavatory faucet to which it is intended to be attached.~~

"Lavatory replacement accessory" means all devices designed to regulate water flow including but not limited to: pressure compensating devices, restricting devices, aerator devices, laminar devices, and spray devices that are sold separately from the lavatory faucet to which it is intended to be attached.

"Plumbing fitting" means a showerhead, lavatory faucet, kitchen faucet, metering faucet, lavatory replacement accessory ~~aerator~~, kitchen replacement accessory ~~aerator~~, wash fountain, or tub spout diverter.

Section 1604. Test Methods for Specific Appliances.

(h) Plumbing Fittings.

(2) The test method for other plumbing fittings is ~~ANSI/ASME A112.19.6-1995~~ ASME A112.18.1-2011/CSA B1.25.1-1.

Section 1605. Energy Performance, Energy Design, Water Performance, and Water Design Standards: In General.

Section 1605.1. Federal and State Standards for Federally-Regulated Appliances.

(1) **Showerheads~~, Faucets, Aerators,~~ and Wash Fountains.** The flow rate of showerheads~~, lavatory faucets, kitchen faucets, lavatory replacement aerators, kitchen replacement aerators~~, wash fountains, and metering faucets shall be not greater than the applicable values shown in Table H-1. Showerheads shall also meet the requirements of ASME/ANSI Standard A112.18.1M-1996, 7.4.4(a).

Table H-1

Standards for Plumbing Fittings

Appliance	*Maximum Flow Rate*
Showerheads	2.5 gpm at 80 psi
~~Lavatory faucets~~	~~2.2 gpm at 60 psi~~
~~Kitchen faucets~~	~~2.2 gpm at 60 psi~~
~~replacement aerators~~	~~2.2 gpm at 60psi~~
Wash fountains	$2.2 \text{ x } \frac{\text{rim space (inches)}}{20}$ gpm at 60psi
Metering faucets	.25 gallons/cycle
Metering faucets for wash fountains	$2.5 \text{ x } \frac{\text{rim space (inches)}}{20}$ gpm at 60psi

(2) **Showerhead-Tub Spout Diverter Combination**. Showerhead-tub spout diverter combinations shall meet both the standard for showerheads and the standard for tub spout diverters.

(3) **Tub Spout Diverters**. See Section 1605.3(h) for standards for tub spout diverters.

(4) **Commercial Pre-rinse Spray Valves**.

(A) The flow rate of commercial pre-rinse spray valves manufactured on or after January 1, 2006 shall be equal to or less than 1.6 gpm at 60 psi.

(B) See Section 1605.3(h) for design standards for commercial pre-rinse spray valves.

(5) **Lavatory Faucets, Replacement Lavatory Accessories, Kitchen Faucets, and Replacement Kitchen Accessories.** See Section 1605.2(h) for water efficiency standards for plumbing fixtures.

Section 1605.2. State Standards for Federally-Regulated Appliances.

(h) Plumbing Fittings.

~~See Sections 1605.1(h) and 1605.3(h) for water efficiency standards for plumbing fittings.~~

(1) **Lavatory Faucets, Replacement Lavatory Accessories, Kitchen Faucets, and Replacement Kitchen Accessories.** The flow rate of lavatory faucets, <u>lavatory replacement accessories,</u> kitchen faucets, kitchen replacement <u>accessories</u>, wash fountains, and metering faucets shall adhere to the applicable values shown in Table H-2.

Table H-2

Standards for Plumbing Fittings

Appliance	*Maximum Flow Rate*	*Minimum Flow Rate*
Lavatory faucets and faucet accessories	1.0 gpm at 60 psi	0.5 gpm at 20 psi
Kitchen faucets and kitchen replacement accessories	1.8 gpm at 60 psi with allowance for temporary flow rate of 2.2 gpm at 60 psi ~~2.2 gpm at 60 psi~~	

Section 1605.3 State Standards for Non-Federally-Regulated Appliances.

(h) Plumbing Fittings.

(4) Other Plumbing Fittings. See Sections 1605.1(h) and 1605.2(h) for energy efficiency standards for plumbing fittings that are federally-regulated consumer products.

Section 1606. Filing by Manufacturers; Listing of Appliances in Database.

Table X - Data Submittal Requirements

	Appliance	*Required Information*	*Permissible Answer*
H	Plumbing Fittings	*Type	Showerhead, lavatory faucet, kitchen faucet, metering faucet, lavatory replacement accessory ~~aerator~~, kitchen replacement accessory ~~aerator~~, wash fountain, lift-type tub spout diverter, turn-type tub spout diverter, pull-type tub spout diverter, push-type tub spout diverter
		Flow Rate - maximum	
		Flow Rate – maximum (for lavatory faucets, lavatory faucet accessories, kitchen faucets, and kitchen faucet accessories)	
		Pulsating (for showerheads only)	Yes, no
		Rim Space (for wash fountains only)	
		Tub Spout Leakage Rate When New	
		Tub Spout Leakage Rate After 15,000 Cycles	

12 References

[75 Fed. Reg.245, 22 December 2010] Federal Register. Waiver of Federal Preemption of State Regulations Concerning the Water Use or Water Efficiency of Showerheads, Faucets, Water Closets and Urinals. 75:245 (22 December 2010). p. 80289.

[77 Fed. Reg.104, 30 May 2012] Federal Register. Test Procedures for Showerheads, Faucets, Water Closets, Urinals, and Commercial Prerinse Spray Valves; Notice of Proposed Rulemaking and Public Hearing. 77:104 (30 May 2012). p. 31742.

[78 Fed. Reg.67, 8 April 2013] Federal Register. Test Procedures for Showerheads, Faucets, Water Closets, Urinals, and Commercial Prerinse Spray Valves; Supplemental Notice of Proposed Rulemaking. 78:67 (8 April 2013). p. 20832.

Ackerman, Frank and Elizabeth A. Stanton. 2012. Stockholm Environment Institute. "Climate Risks and Carbon Prices: Revising the Social Cost of Carbon." http://www.economics-ejournal.org/economics/journalarticles/2012-10. Economics. April 4.

Alliance for Water Efficiency. 2012. Assessing the Economic and Environmental Benefits of Industrial Water Use Efficiency.

Amazon.com. "Customer Reviews: 0.5 GPM Low Flow Dual-Thread Faucet Aerator - Kitchen & Bathroom." Accessed July 2013. http://www.amazon.com/0-5-Flow-Dual-Thread-Faucet-Aerator/product-reviews/B0034UMZA6/ref=dp_top_cm_cr_acr_txt?ie=UTF8&showViewpoints=1.

ASME. 2011. Plumbing Fittings with Update No. 1. A112.18.1/CSA B125.1 – 2011

Aquacraft, Inc. Water Engineering and Management. Seattle Home Water Conservation Study: the Impacts of High Efficiency Plumbing Fixture Retrofits in Single-family Homes.2000. Prepared for Seattle Public Utilities and the United States Environmental Protection Agency. http://www.aquacraft.com/sites/default/files/pub/Mayer-%282000%29-Seattle-Home-Water-Conservation-Study.pdf. Boulder, Colo.: Aquacraft, Inc. Water Engineering and Management

___. Residential Indoor Water Conservation Study: Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-family Homes in the East Bay Municipal Utility District Service Area. 2003. Prepared for East Bay Municipal Utility District and the United States Environmental Protection Agency.

___. Tampa Water Department Residential Water Conservation Study: The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes. 2004. Prepared for Tampa Water Department and The United States Environmental Protection Agency. http://www.aquacraft.com/sites/default/files/pub/Mayer-%282004%29-Tampa-Water-Department-Residential-Water-Conservation-Study.pdf Boulder, Colo.: Aquacraft, Inc. Water Engineering and Management.

___. California Single Family Water Use Efficiency Study. 2011. Prepared by DeOreo, W., Mayer, P., Martien, L., Hayden, M., Funk, A., Kramer-Duffield, M. & R. Davis. http://www.aquacraft.com/node/63. Boulder, Colo.: Aquacraft, Inc. Water Engineering and Management.

Brown, Richard E. and Jonathan G. Koomey. 2002. "Electricity Use in California: Past Trends and Present Usage Patterns." Energy Policy (also LBNL-47992). vol. 31, no. 9. July. pp. 849-864.

Black & Veatch. "2009/2010 50 Largest Cities Water/Wastewater Rate Survey." 2010.

[Raftelis 2008]. Raftelis Financial Consultants, Inc. 2008 "Water and Wastewater Rate Survey." Prepared for American Water Works Association. Values from Western Region.

___. 2011 "2011 California-Nevada Water Rate Survey." Prepared for California-Nevada Section, American Water Works Association.

[CARB] California Air Resources Board. 2008a. AB 32 Technical Stakeholder Working Group Meeting. Cost-Effectiveness. http://www.arb.ca.gov/cc/scopingplan/economics-sp/meetings/060308/ce_white_paper.pdf. June 3.

___. 2008b. Climate Change Scoping Plan Appendices Volume II: Analysis and Documentation. http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume2.pdf. December.

___. 2010. Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D. http://www.arb.ca.gov/regact/2010/res2010/res10isor.pdf. Accessed July 24, 2013.

___. 2011a. California Air Resources Board. Appendix C: Cost Effectiveness Calculation Methodology. http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/appc_3_10_11.pdf. March 10.

___. 2011b. Emission Reduction Offsets Transaction Cost Summary Report for 2011. http://www.arb.ca.gov/nsr/erco/erco.htm.

___. 2012. Emission Reduction Offsets Transaction Cost Summary Report for 2012. http://www.arb.ca.gov/nsr/erco/erco.htm.

___. 2013a. Mail-Out #MSC 13-09. http://www.arb.ca.gov/msprog/mailouts/msc1309/msc1309.pdf. March 25.

___. 2013b. California Air Resources board Quarterly Auction 3, May 2013 – Summary Results Report. www.arb.ca.gov/cc/capandtrade/auction/may-2013/results.pdf.

[CBSC] California Building Standards Commission. 2010. 2010 California Green Building Standards Code California Code of Regulations, Title 24, Part 11. Sacramento, CA. ISBN 978-1-58001-979-8. http://www.documents.dgs.ca.gov/bsc/CALGreen/2010_CA_Green_Bldg.pdf.

[CEC] California Energy Commission. 1978. Conservation Division Regulations for Appliance Efficiency Standards, (including requirements for Intermittent Ignition Devices). Amended, July 19, 1978.

___. 2005. "Hot Water Distribution System Research – Phase I." Prepared by Applied Energy Technology. Public Interest Energy Research Program. November 2005. Report number: CEC-500-2005-161. http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

___. 2006. "Refining Estimates of Water-related Energy Use in California." Prepared by Navigant Consulting, Inc., Public Interest Energy Research Program. December 2006. Report number:

CEC-500-2006-118. http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

___. 2009. “California Statewide Residential Appliance Saturation Study. 2009”. Saturation Report: Water Heating, Cleaned primary water heater fuel. Accessed July 2013.

___. 2012. Adopted California Energy Commission Demand Forecast Report 2012-2022. Mid-Case Final Demand Forecast. Updated September 19, 2012.

___. 2013a. Appliance Efficiency Database.

___. 2013b California Energy Commission. 2013. Comments on the Invitation to Participate in the 2013 Appliance Efficiency Rulemaking. Sacramento, CA http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Water_Appliances_12-AAER-2C/.

___. 2013c. California Energy Commission. California Building Efficiency Standards (Title 24) Residential Alternate Calculation Reference Manual: Appendix E - Water Heating Calculation Method. http://www.energy.ca.gov/2013publications/CEC-400-2013-003/CEC-400-2013-003-SD-REV.pdf.

California Sustainability Alliance. 2013. “Water - Energy Toolkit For Sustainable Development : A Practical Guide To Implementing Water-Energy Conservation Policies And Projects For Local Governments, Developers, Water Agencies And Supporting Parties.”

[CalGreen 2012a] California Building Standards Commission. Final Express Terms for Proposed Building Standards of the California Building Standards Commission Regarding Adoption of Amendments for the 2013 California Buildings Standards Code, Title 24, California Code of Regulations (CCR), Part 11 California Green Building Standards Code. 2012. Sacramento, CA. http://www.documents.dgs.ca.gov/bsc/prpsd_chngs/documents/2012/BSC-07-12-ET-Pt11-Final.pdf

[CalGreen 2012b] California Building Standards Commission. Final Express Terms for Proposed Building Standards of the Department of House and Community Development regarding the 2013 California Green Buildings Standards Code (CalGreen) California Code of Regulations, Title 24, Part 11 (HCD). 2012. Sacramento, CA. http://www.documents.dgs.ca.gov/bsc/prpsd_chngs/documents/2012/HCD-04-12-FET-Pt11.pdf.

[CA IOUs] California Investor Owned Utilities. Codes and Standards Enhancement (CASE) Report: Single Family Water Heating Distribution System Improvements. September 2011.

[Cal PRC §25402] California Public Resources Code, Section 25402.

Christian-Smith, Juliet; Heberger, Matthew; and Luch Allen. Urban Water Demand in California to 2100: Incorporating Climate Change. 2012. Pacific Institute. http://www.pacinst.org/reports/urban_water_demand_2100/full_report.pdf.

[City of Los Angeles] City of Los Angeles, California. 2009. Water Efficiency Requirements for New Development and Renovations of Existing Buildings. Ordinance Number 180822. http://clkrep.lacity.org/onlinedocs/2009/09-0510_ord_180822.pdf

[City of New York] City of New York, New York. “Local Law No. 54. To amend the administrative code of the city of New York, in relation to enhanced water efficiency standards." 2010. http://www.nyc.gov/html/dob/downloads/pdf/ll57of2010.pdf.

[CPUC 2011a] California Public Utilities Commission Energy Division (2011). Embedded Energy in Water Studies. Study 3: End-use Water Demand Profiles. Prepared by Aquacraft Inc. DeOreo, W., Mayer, P., Martien, L., Hayden, M., Funk, A., Kramer-Duffield, M. & R. Davis.. CALMAC Study ID CPU0052.

[CPUC 2011b] California Public Utilities Commission. 2011. Evaluation, Measurement, and Verification of the California Investor Owned Utilities' Embedded Energy in Water Pilot Programs. Prepared by ECONorthwest. http://www.energydataweb.com/cpucFiles/33/FinalEmbeddedEnergyPilotEMVReport_1.pdf.

[CPUC 2011c] California Public Utilities Commission. 2011.Order Approving Pilot Water Conservation Programs Within the Energy Utilities' Energy Efficiency Programs. December 20, 2007. Decision 07-12-050.

[CWI 2010a] Conservation Warehouse International. "PCA® Perlator ®Faucet aerator - 1.5 gpm max Pressure compensating Regular Size – Technical Specification Sheet." Copyright 2010 by NEOPERL.

[CWI 2010b] Conservation Warehouse International. "PCA® Perlator ®Faucet aerator - 1.0 gpm max Pressure compensating Regular Size – Technical Specification Sheet." Copyright 2010 by NEOPERL.

[CWI 2010c] Conservation Warehouse International. "PCA® Perlator ®Spray Faucet Attachment – 0.5gpm max Pressure compensating Regular Size – Technical Specification Sheet." Copyright 2010 by NEOPERL.

Delta Faucet. 2013. Trouble Shooting a Leaking Faucet: Delta Faucet. http://www.deltafaucet.com/customersupport/troubleshoot/bath-mini-widespread.html

[DOE] U.S. Department of Energy. Technical Document for "Energy Efficiency Standards for Pool Heaters, Direct Heating Equipment and Water Heaters " Chapter: 10 : National Impact Analysis. June 15, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0170.

[DOE] U.S. Department of Energy. (2011). Energy Efficiency Standards for Pool Heaters, Direct Heating Equipment and Water Heaters. Docket ID: EERE-2006-STD-0129. Technical Support Document: Chapter 10 - National Impact Analysis. June 2011. Table 10.3.1 Gas-Fired Storage Water Heaters: Energy Efficiency Distributions in 2015 and Table 10.3.2 Electric Storage Water Heaters: Energy Efficiency Distributions in 2015.

[DOE] Department of Energy. 2013. Energy Conservation Program: Energy Conservation Standards for Standby Mode and Off Mode for Microwave Ovens. http://www.regulations.gov/#!docketDetail;rpp=10;po=0;D=EERE-2011-BT-STD-0048. June 17.

[DOL] United States Department of Labor. 2012. Bureau of Labor Statistics, CPI Inflation Calculator. http://www.bls.gov/data/inflation_calculator.htm. Accessed June 13, 2013.

[EBMUD 2002] East Bay Municipal Utility District Water Conservation District. 2002. Water Conservation Market Penetration Study. http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf. San Francisco, Cali.: Water Resources Engineering, Inc.

[EBMUD 2003] East Bay Municipal Utility District & The United States Environmental Protection Agency. 2003. "Residential Indoor Water Conservation Study: Evaluation of High-Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July 2003. Prepared by DeOreo W., Mayer P., Lewis D., and Towler E. (Aquacraft, Inc. Water Engineering and Management). http://www.ebmud.com/sites/default/files/pdfs/residential_indoor_wc_study_0.pdf.

Georgia Senate Bill 370. State Senator Ross Tolleson. 2009 – 2010 Regular Session. http://www.gaepd.org/Files_PDF/Water/SB370%20rpt%20review%20Final.pdf

Horii, Brian and Dr. Jim Williams, Energy and Environmental Economics. 2013. CPUC Workshop on Societal Cost Test. http://www.cpuc.ca.gov/NR/rdonlyres/E7263960-03C4-4BB2-8FD2-2FBF7DAD3436/0/SCTWorkshop6102013.pdf. June.

[Interagency Working Group] Interagency Working Group on Social Cost of Carbon, United States Government. 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf.

Johnson, Laurie T. and Chris Hope. 2012. Journal of Environmental Studies and Sciences, Journal no. 13412. The social cost of carbon in U.S. regulatory impact analyses: an introduction and critique. http://www.eenews.net/assets/2012/09/17/document_gw_05.pdf. September 12.

McNeil M., Dunham Whitehead C., Letschert V., della Cava M., 2008 "National Water Saving Model For EPA WaterSense." Presentation to American Water Works Association. February 12, 2008. http://www.awwa.org/files/Resources/Waterwiser/references/PDFs/sustainable2008_tue11-6.pdf.

[NAHB 2007] National Association of Home Builders & Bank of America Home Equity. "Bank of America Home Equity Study of Life Expectancy of Home Components". 2007. Prepared by the Economics Group at NAHB.

NEOPERL. 2012. NEOPERL ® Wholesale Price List Catalog 3.

NEOPERL. 2013. Streams|Wholesale Products|Neoperl http://www.neoperl.com/wholesale/aerator-flow-streams.aspx

Niagara Conservation. 2013. Dual Thread Aerators N3104, N3210, N321- Features and Benefits. http://www.niagaraconservation.com/resources/dyn/files/1048694zad0cae0/_fn/Aerators_Dual+Thread_PC+MSS3104_3210_3215-02.pdf.

San Joaquin Valley UAPCD. 2008. Final Staff Report: Update to Rule 2201 Best Available Control Technology (BACT) Cost Effectiveness Thresholds.

http://www.valleyair.org/busind/pto/bact/May%202008%20BACT%20cost%20effectiveness%20threshold%20update%20staff%20report.pdf. May 14.

[SWRCB] California Environmental Protection Agency State Water Resources Control Board. 20x2020 Water Conservation Plan. February 2010.

Tanner, Stephanie (U.S. EPA WaterSense). 2012. Personal Communication. October 25.

U.S. Code of Federal Regulations at 10 CFR Part 430.32.

U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, American Community Survey, Census of Population and Housing, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits Last Revised: Thursday, 27-Jun-2013 13:52:14 EDT

__. "Consumer Price Index: U.S. city average (not seasonally adjusted), Water and sewerage maintenance, Base Period:1982-84=10,0Series Id: CUUR0000SEHG01." 2013.

[U.S. BLS] United States Bureau of Labor Statistics. "Employment Projections: 2010-2020 Summary." News Release from February 1, 2012. USDL-12-0160.

[U.S. EPS] "Water: Sustainable Infrastructure: Sustainable Water Infrastructure." EPA Water Website. Accessed July 2013. http://water.epa.gov/infrastructure/sustain/wec_wp.cfm.

[EPAct 1992] U.S. House. 102th Congress, 1st Session. H.R. 766, Energy Policy Act of 1992. Washington, Government Printing Office, 1992.

[WaterSense 2007a] U.S.EPA WaterSense. 2007. "EPA WaterSense ® Response to Public Comments Received on February 2007 Draft WaterSense® High-Efficiency Bathroom Sink Faucet Specification." http://www.epa.gov/WaterSense/docs/faucet_comment_response508.pdf.

__. 2007b. "High-Efficiency Lavatory Faucet Specification." 2007.

__. 2007c U.S.EPA WaterSense. "U.S.EPA WaterSense ® High-Efficiency Lavatory Faucet Specification Supporting Statement". 2007http://www.epa.gov/WaterSense/docs/faucet_suppstat_final508.pdf.

__. 2013a. "Database of WaterSense Labeled Urinals." Accessed July 2013.

__. 2013b. "WaterSense: Our Water: Why Water Efficiency." WaterSense Website. Accessed July 2013. http://www.epa.gov/watersense/our_water/why_water_efficiency.html.

Appendix A: Embedded Energy in Water

The embedded energy value used in the analysis is 10,045 kWh/million gallons of water (MG). This value was derived from a California Energy Commission PIER study (CEC 2006), which states the embedded energy values shown in the table below "are sufficient for informing policy and prioritization of research and development investments."

Table A.1 Recommended Embedded Energy Estimates

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

Source: CEC 2006. Table 7.

The total regional values shown in Table A.1 were weighted based on the population in Northern and Southern California in 2011 (U.S. Census Bureau).[6] All water used in faucets is used indoors, so only the indoor embedded energy values apply.

The California Public Utilities Commission (CPUC) has conducted additional research on embedded energy since the CEC's 2006 report was released. However, the values presented in the CEC's 2006 report are still the most up-to-date values recommended for use to inform policies the CASE Team has used the CEC's 2006 embedded energy values for this analysis.

The CPUC has made notable progress in improving understanding of the relationship between water and energy in California. CPUC's Decision 07-12-050, issued December 20, 2007, authorized the largest electricity utilities to partner with water utilities and administer pilot programs that aimed to save water and energy (CPUC 2011c). The Decision also authorized three studies to validate claims that saving water can save energy and explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. The pilot programs succeed at demonstrating that water conservation measures also result in energy savings.

The CPUC studies were effective at obtaining a more granular understanding of how energy use varies based on a number of factors including supply, (i.e. surface, ground, brackish, or ocean desalination), geography, and treatment technology. The authors found "that the value of energy embedded in water is higher than initially estimated in the CEC's 2005 and 2006 studies." Although the data collected for the studies is the most comprehensive set of data on energy used to meet water demand, the data is still just a small sampling of all the potential data points in California. Since the authors did not find strong patterns within the sample data and there was no strong evidence that the sample data was representative for a particular region, process, or technology

[6] Northern and Southern California populations are 39.1% and 60.9% of total California population, respectively.

type, the authors did not have a strong basis to estimate the embedded energy values for specific geographic regions. Further, the CPUC studies did not recommend changes to the embedded energy values presented in the CEC's 2006 report.

While the CASE Report analysis uses the embedded energy values associated with water supply and conveyance, there is no evidence that reducing water use at the building level will impact water supply and conveyance activities. Thus water efficiency standards may result in reductions to energy used to supply and convey water.

Appendix B: Cost Analysis Assumptions

The cost analysis presented in this CASE Report assumes that cost savings will be realized through lower electricity, gas, and water bills. Electricity and gas savings are due to a reduction in the amount of energy required to heat water. There are no cost savings associated with embedded energy savings. The electricity, natural gas, and water rates used in this analysis are presented below.

Electricity Rates

The electricity rates used in the analysis of this CASE Report were derived from projected future prices for residential, commercial and industrial sectors in the CEC's "Mid-case" projection of the 2012 Demand Forecast (2012), which used a 3% discount rate and provide prices in 2010 dollars. The sales weighted average of the 5 largest utilities in California was converted to 2013 dollars using an inflation adjustment of 1.07 (DOL 2013). See the rates by year below in Table B.1.

Table B.1 Statewide Weighted Average Electricity Rates 2015 - 2040 (PG&E, SCE, SDG&E, LADWP and SMUD - 5 largest Utilities) in 2013 cents/kWh

Year	Residential Electricity Rate (2013 cents/kWh)
2015	16.82
2016	17.02
2017	17.24
2018	17.47
2019	17.71
2020	18.00
2021	18.34
2022	18.70
2023	19.06
2024	19.43
2025	19.81
2026	20.19
2027	20.59
2028	20.98
2029	21.39
2030	21.81

Natural Gas Rates

The natural rates used in the analysis of this CASE Report were derived from projected future prices for residential, commercial and industrial sectors in the CEC's "Mid-case" projection of the 2012 Demand Forecast (2012), which used a 3% discount rate and provide prices in 2010 dollars. The sales weighted average of the three largest utilities in California was converted to 2013 dollars using an inflation adjustment of 1.07 (DOL 2013). See the rates by year below in Table B-2.

Table B.2 Statewide Weighted Average Electricity Rates 2015 - 2040 (PG&E, SCE, and SDG&E - 3 largest Utilities) in 2013$/therm

Year	Residential Electricity Rate (2013$/ther,)
2015	0.86
2016	0.86
2017	0.87
2018	0.89
2019	0.90
2020	0.93
2021	0.95
2022	0.98
2023	1.01
2024	1.04
2025	1.07
2026	1.10
2027	1.13
2028	1.16
2029	1.19
2030	1.23

Water Rates

The potable water rates used in the analysis presented in this CASE Report are based on water rate data from Raftelis Financial Consultants Inc. (Raftelis 2008, Raftelis 2011). The residential potable water rate was derived using data from a 2011 study of rates from 216 water utilities in California. The commercial rates are derived from the 2008 American Water Works Association Water and Wastewater Survey using values from the western region.

Wastewater rates are based on data from Black & Veatch on rates in the eight largest cities[7] in California (Black & Veatch 2010). About 30 percent of Californians live in one of these eight cities, and it is assumed that these city's rates are representative of rates throughout the state. The CASE analysis uses the population-weighted wastewater rate from the eight cities. The 2009 residential rate is based on cost data that assumes customers use 15,000 gallons per month. The 2009 commercial wastewater rates were derived from cost data that assumes customers use 100,000 gallons per month.

Future potable water and wastewater rates were projected based on the Consumer Price Index (CPI) for Water and Sewer Maintenance and assuming a 3 percent annual discount rate. In recent years water rates have been increasing faster than CPI projections (Black & Veatch 2010, Raftelis 2011). It is likely that water rates will increase faster than the CAES analysis predicts, and it follows that the cost savings presented in this report could understate the true potential savings. See the rates by year below in Table 8-3.

[7] The eight largest cities in California are: Fresno, Long Beach, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, and San Jose.

Table B-3 Statewide Average Potable Water and Wastewater Rates 2015 - 2040 in 2013$/1000gal

Year	Residential Rate Potable Water and Wastewater Rates (2013$ / 1000 gal)		
	Potable Water	Waste-water	Total
2015	$2.82	$4.66	$7.49
2016	$2.88	$4.77	$7.66
2017	$2.95	$4.88	$7.83
2018	$3.01	$4.98	$8.00
2019	$3.08	$5.09	$8.17
2020	$3.14	$5.20	$8.34
2021	$3.21	$5.30	$8.51
2022	$3.27	$5.41	$8.68
2023	$3.33	$5.51	$8.85
2024	$3.40	$5.62	$9.02
2025	$3.46	$5.73	$9.19
2026	$3.53	$5.83	$9.36
2027	$3.59	$5.94	$9.53
2028	$3.65	$6.04	$9.70
2029	$3.72	$6.15	$9.87
2030	$3.78	$6.26	$10.04

Appendix C: Criteria Pollutant Emissions and Monetization

C.1 Criteria Pollutant Emissions Calculation

To calculate the statewide emissions rate for California, the incremental emissions between CARB's high load and low load power generation forecasts for 2020 were divided by the incremental generation between CARB's high load and low load power generation forecast for 2020. Incremental emissions were calculated based on the delta between California emissions in the high and low generation forecasts divided by the delta of total electricity generated in those two scenarios. This emission rate per MWh is intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario instead of the high load scenario. While emission rates may change somewhat over time, 2020 was considered a representative year for this measure.

C.2 Criteria Pollutant Emissions Monetization

Avoided ambient ozone precursor and fine particulate air pollution benefits were monetized based on avoided control costs rather than damage costs due to the availability of emission control cost-effectiveness thresholds, as well as challenges in quantifying a specific value for damages per ton of pollutants.

Two sources of data for cost-effectiveness thresholds were evaluated. The first is Carl Moyer cost-effectiveness thresholds for ozone precursors and fine particulates (CARB 2011a, CARB 2013a and 2013b). The Carl Moyer program has provided incentives for voluntary reductions in criteria pollutant reductions from a variety of mobile combustion sources as well as stationary agricultural pumps that meet specified cost-effectiveness cut-offs.

The second is the San Joaquin Valley UAPCD Best-Available Control Technology ("BACT") cost-effectiveness thresholds study. Pollution reduction technologies that are not yet demonstrated in practice (in which case they are required without a cost-effectiveness evaluation) can be required at new power plants and other sources if technologically feasible and within cost-effectiveness thresholds. San Joaquin Valley UAPCD conducted a state-wide study as the basis for updating their BACT thresholds in 2008.

This CASE report relies primarily on the Carl Moyer thresholds due to their state-wide nature and applicability to combustion sources[8]. In addition, the Carl Moyer fine particulate values for fine particulate apply to combustion sources with specific health impacts, while BACT thresholds include both combustion sources and dust. The Carl Moyer values are somewhat more conservative for ozone precursors than San Joaquin Valley UAPCD BACT thresholds, and significantly higher for fine particulate[9].The Carl Moyer program does not address sulfur oxides, however, thus the San Joaquin BACT thresholds were used for this pollutant.

Price reports for California Emission Reduction Credit (ERCs, i.e. air pollution credits purchased to offset regulated emission increases) for 2011 and 2012 were also compared to the values selected

[8] Further evaluation of the qualitative impacts of combustion fine particulate emissions from power generation and transportation sources may be beneficial.

[9] We note that both the Carl Moyer and San Joaquin Valley UAPCD BACT cost-effectiveness thresholds for fine particulates fall within the wide range of fine particulate ERC trading prices in California in 2011 and 2012.

in this CASE report. For each pollutant there is a wide range of ERC values per ton that are both higher and lower than the values per ton used in this CASE report [CARB 2011b and 2012]. Due to wide variability and low trading volumes, ERC values were evaluated for comparative purposes only.

Appendix D: Greenhouse Gas Valuation Discussion

The climate impacts of pollution from fossil fuel combustion and other human activities, including the greenhouse gas effect, present a major risk to global economies, public health and the environment. While there are uncertainties of the exact magnitude given the interconnectedness of ecological systems, at least three methods exist for estimating the societal costs of greenhouse gases: 1) the Damage Cost Approach 2) the Abatement Cost Approach and 3) the Regulated Carbon Market Approach. See below for more details regarding each approach.

D.1 Damage Cost Approach

In 2007, the U.S. Court of Appeals for the Ninth Circuit ruled that the National Highway Transportation Traffic Safety Administration (NHTSA) was required to assign a dollar value to benefits from abated carbon dioxide emissions. The court stated that while there are a wide range of estimates of monetary values, the price of carbon dioxide abatement is indisputably non-zero. In 2009, to meet the necessity of a consistent value for use by government agencies, the Obama Administration established the Interagency Working Group on the Social Cost of Carbon to establish official estimates (Johnson and Hope).

The Interagency Working Group primarily uses estimates of avoided damages from climate change which are valued at a price per ton of carbon dioxide, a method known as the damage cost approach.

D.2 Interagency Working Group Estimates

The Interagency Working Group SCC estimates, based on the damage cost approach, were calculated using three climate economic models called integrated assessment models which include the Dynamic Integrated Climate Economy (DICE), Policy Analysis of the Greenhouse Effect (PAGE), and Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) models. These models incorporate projections of future emissions translated into atmospheric concentration levels which are then translated into temperature changes and human welfare and ecosystem impacts with inherent economic values. As part of the Federal rulemaking process, DOE publishes estimated monetary benefits using Interagency Working Group SCC values for each Trial Standard Level considered in their analyses, calculated as a net present value of benefits received by society from emission reductions and avoided damages over the lifetime of the product. The recent U.S. DOE Final Rulemaking for microwave ovens contains a Social Cost of Carbon section that presents the Interagency Working Group's most recent SCC values over a range of discount rates (DOE 2013) as shown in Table D-1. The two $ metric ton of values used in this CASE report were taken from the two highlighted columns, and converted to 2013 dollars.

Table D.1 Social Cost of CO_2 2010 – 2050 (in 2007 dollars per metric ton of CO_2) (source: Interagency Working Group on Social Cost of Carbon, United States Government, 2013)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The Interagency Working Group decision to implement a global estimate of the SCC rather than a domestic value reflects the reality of environmental damages which are expected to occur worldwide. Excluding global damages is inconsistent with U.S. regulatory policy aimed at incorporating international issues related to resource use, humanitarian interests, and national security. As such, a regional SCC value specific to the Western United States or California specifically should be at similarly inclusive of global damages. Various studies state that certain values may be understated due to the asymmetrical risk of catastrophic damage if climate change impacts are above median predictions, and some estimates indicate that the upper end of possible damage costs could be substantially higher than indicated by the IWG (Ackerman and Stanton 2012, Horii and Williams 2013).

D.3 Abatement Cost Approach

Abating carbon dioxide emissions can impose costs associated with more efficient technologies and processes, and policy-makers could also compare strategies using a different by estimating the annualized costs of reducing one ton of carbon dioxide net of savings and co-benefits. The cost of abatement approach could reflect established greenhouse gas reduction policies and establish values for carbon dioxide reductions relative to electricity de-carbonization and other measures. (While recognizing the potential usefulness of this method, this report utilizes the IWG SCC approach and we note that the value lies within the range of abatement costs discussed further below.)

The cost abatement approach utilizes market information regarding emission abatement technologies and processes and presents a wide-range of values for the price per ton of carbon dioxide. The California Air Resources Board data of the cost-effectiveness of energy efficiency measures and emission regulations would provide one source of potential data for an analysis under this method. To meet the AB 32 target, ARB has established the “Cost of a Bundle of Strategies Approach” which includes a range of cost-effective strategies and regulations (CARB 2008b). The results of this approach within the framework of the Climate Action Team Macroeconomic Analysis are provided for California, Arizona, New Mexico, the United States, and a global total identified in that same report, as shown in Table D-2 below.

Table D.2 Cost-effectiveness Range for the CAT Macroeconomic Analysis

Exhibit 3: Cost-effectiveness Range for the CAT Macroeconomic Analysis, Selected States, United States, Global -

State	Cost-effectiveness Range $/ ton CO_2eq	Tons Reduced MMtCO_2e/yr	Percent of BAU
California 2020 (CAT[1], CEC[2])	- 528 to 615	132	22
Arizona[3] 2020	- 90 to 65	69	47
New Mexico[4] 2020	- 120 to105	35	34
United States (2030)[5]	-93 to 91	3,000	31
Global Total (2030)	-225 to 91	26,000	45

Source:
1. Climate Action Team Updated Macroeconomic Analysis of Climate Strategies, Presented in the March 2006 Climate Action Team Report, September 2007.
2. California Energy Commission, *Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California*, July 2005, ICF ($/MTC$O_2$eq).
3. Arizona Climate Change Advisory Group, *Climate Change Action Plan*, August 2006, ($/MTC$O_2$eq).
4. New Mexico Climate Change Advisory Group, Final Report, December 2006.
5. McKinsey & Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* December 2007.
6. The McKinsey Quarterly, McKinsey & Company, *A Cost Curve for Greenhouse Gas Reduction*, Fall 2007.

Source: CARB 2008b

Energy and Environmental Economics (E3) study defines the cost abatement approach more specifically as electricity de-carbonization and is based on annual emissions targets consistent with existing California climate policy. Long-term costs are determined by large-scale factors such as electricity grid stability, technological advancements, and alternative fuel prices. Near-term costs per ton of avoided carbon could be$200/ton in the near-term (Horii and Williams 2013), thus as noted earlier the value used in this report may be conservative.

D.4 Regulated Carbon Market Approach

Emissions allowance markets provide a third potential method for valuing carbon dioxide. Examples include the European Union Emissions Trading System and the California AB32 cap and trade system as described below. Allowances serve as permits authorizing emissions and are traded through the cap-and-trade market between actors whose economic demands dictate the sale or purchase of permits. In theory, allowance prices could serve as a proxy for the cost of abatement. However, this report does not rely on the prices of cap-and-trade allowances due to the vulnerability of the allowance market to external fluctuations, and the influence of regulatory decisions affecting scarcity or over-allocation unrelated to damages or abatement costs.

D.4.1 European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) covers more than 11,000 power stations, industrial plants, and airlines in 31 countries. However, the market is constantly affected by over-supply following the 2008 global recession and has seen prices drop to dramatic lows in early 2013, resulting in the practice of "back-loading" (delaying issuances of permits) by the European parliament. At the end of June 2013, prices of permits dropped to $5.41/ton, a price which is well below damage cost estimates and sub-optimal for encouraging innovative carbon dioxide emission abatement strategies.

D.4.2 California Cap & Trade

In comparison, California cap-and-trade allowance prices were reported to be at least $14/ton in May of 2013, with over 14.5 million total allowances sold for 2013 (CARB 2013b). However, cap-and-trade markets are likely to cover only subsets of emitting sectors of the industry covered by AB 32. In addition, the market prices of allowances are determined only partly by costs incurred by society or industry actors and largely by the stringency of the cap determined by regulatory agencies and uncontrollable market forces, as seen by the failure of the EU ETS to set a consistent and effective signal to curb carbon dioxide emissions.