M.CUBED
POLICY ANALYSIS FOR THE PUBLIC AND PRIVATE SECTORS

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DATE: August 30, 2016
TO: Peter Brostrom, DWR
FR: David Mitchell
RE: Projected Statewide and County-Level Effects of Plumbing Codes and Appliance Standards on Indoor GPCD

Summary of Findings

M.Cubed was retained by DWR and the State Water Board to project future reductions in indoor water use from plumbing codes and appliance standards. The projections were developed with dynamic plumbing fixture inventory growth and replacement models and Department of Finance (DOF) forecasts of county-level population and housing growth. Model performance was benchmarked against empirical estimates of average plumbing fixture efficiency and water use where such estimates were available. Key modeling results include:

- Relative to a 2015 baseline efficiency level, plumbing codes and appliance standards are projected to reduce M&I per capita water use by 9 to 10 GPCD by 2040. This equates to a savings in statewide M&I water use in 2040 of between 465 and 538 thousand acre-feet (TAF). Estimated reductions in M&I GPCD by county are provided in Attachment 3. These results are discussed in more detail in Section 5.3.

- Approximately two-thirds of projected water savings are associated with toilets and urinals and one-third with clothes washers. As discussed in Section 2.3, significant reductions in shower and faucet water use are not anticipated. Clothes washers are expected to have the greatest impact in the single-family sector, where clothes washer ownership rates are highest. These results are discussed in more detail in Sections 5.1-5.3.

- More than half (57 percent) of the projected reduction in water use is expected to come from the single-family residential sector. Approximately 20 percent is expected to come from the multi-family residential sector. The remaining, 23 percent is associated with non-residential toilets, urinals, and commercial clothes washers. These results are discussed in more detail in Sections 5.1-5.3.

- Plumbing codes and appliance standards, by themselves, are projected to reduce statewide R-GPCD by approximately 7.6 gallons by 2040.[1] In 2015, indoor R-GPCD averaged about 59 gallons per day, so the projected reduction by 2040 is equivalent to about 13 percent of current R-GPCD. These results are discussed in more detail in Section 5.4. Estimated reductions in R-GPCD

[1] R-GPCD is average per capita water use in the single- and multi-family residential sectors. Urban water suppliers report R-GPCD to the State Water Board as part of their monthly water use report. Most of the variability in monthly R-GPCD is associated with outdoor water use.

by hydrologic region and county are provided in Section 5.5.

- R-GPCD in new homes fitted with EPA WaterSense labeled products averages 36 gallons (DeOreo, et al., 2011). The difference in indoor water use between the average residence in California and such a home is about 23 GPCD. Plumbing codes and appliance standards on their own are projected to reduce this difference by a third to 15 GPCD by 2040.

- The results from this study can be used to inform projections of baseline indoor R-GPCD over time. These baselines, in turn, can be used in the development of indoor R-GPCD reduction targets. The county-level estimates will enable the baselines to reflect regional differences due to age of the housing stock, differences in projected population and housing growth, differences in household density, and other factors affecting residential indoor water use, though the modeling done for this study suggests the impact of such differences on projected R-GPCD savings is not large across extensive geographic areas such as counties or hydrologic regions. They may be more significant across smaller geographic units such as utility service areas. The models developed for this study can easily be adapted to small geographic units of analysis.

- The study results can also help policymakers understand the underlying rate of transformation of the existing inventory of non-efficient plumbing fixtures. Because the models developed for this study are dynamic, they provide insight into how fast or slow appliance efficiency can be expected to change over time under existing codes and standards. This can be useful for establishing timeframes for meeting water use targets.

1 Introduction and Overview

Efficiency standards for toilets, urinals, clothes washers, and showerheads have had a significant impact on indoor water use overtime. For example, average daily per capita water use in single-family households for toilets and clothes washers has decreased by 23 and 36 percent, respectively, since 1999.[2] These changes have largely been powered by national and state-level water use efficiency standards for toilets and clothes washers.

Going forward, efficiency standards for indoor water using fixtures and appliances will continue to reduce indoor water demands. Nationally, the latest residential end uses of water study estimated that 54% of existing washers, 63% of toilets, and 20% of showerheads are low efficiency. As these fixtures turnover, additional gains in indoor water use efficiency will be realized.[3]

Executive Order B-37-16 directs the Department of Water Resources (DWR) and State Water Board to:

> [D]evelop new water use efficiency targets as part of a long-term conservation framework for urban water agencies. These targets go beyond the 20 percent reduction in per capita urban water use by 2020 that was embodied in SB X7-7 of 2009, and will be customized to fit the unique conditions of each water supplier.

In carrying out this charge, it will be important to have a good understanding of how plumbing codes and appliance standards are likely to impact indoor water use over time.

1.1 Scope of Work

M.Cubed was retained by DWR and the State Water Board to develop data and models to estimate the potential additional water savings through 2040 due to the ongoing effects of plumbing codes and appliance standards. This work was divided into the following four tasks:

1. Data Collection
2. Model Development, Estimation, and Benchmarking
3. County-level and Statewide Water Savings Analysis
4. Report of Findings and Conclusions

This Technical Memorandum (TM) is the culmination of Task 4. Its purpose is to (1) describe the methodology and data used to project future water savings from plumbing codes and appliance standards for California's 58 counties; (2) benchmark model performance against empirical estimates of historical plumbing fixture average efficiency and water use where such estimates are available; (3) summarize model results in terms of aggregate and per capita water demand reduction by county and statewide; and (4) discuss the potential uses and policy implications of these results.

1.2 Organization of TM

The remainder of this TM is organized as follows. Section 2 provides a review of the plumbing codes and appliance standards modeled for this analysis. Section 3 presents the methodology and data used to model plumbing fixture and appliance inventories, growth and replacement, average efficiencies, and water use. Section 4 discusses the model results and how they compare to empirical estimates of

[2] Water Research Foundation (2016). Residential End Uses of Water, Version 2. PDF Report #4209b.

[3] Saturation rates in California, particularly for toilets, are higher than national rates, but significant potential remains.

historical average fixture efficiencies. Section 5 summarizes projected aggregate and per capita water savings. Section 6 provides a summary and conclusions of this research.

2 Plumbing Codes and Appliance Efficiency Standards

This section discusses existing state and national plumbing codes and appliance standards, including timing and enforcement, particularly as it relates to SB 407 plumbing retrofit requirements.

2.1 Existing Codes and Standards

The following plumbing codes and appliance standards form the basis for the estimated volumes of future indoor water savings:

- AB 715, enacted in 2007, requires that any toilet or urinal sold or installed in California on or after January 1, 2014 cannot have a flush rating exceeding 1.28 and 0.5 gallons per flush, respectively. AB 715 superseded the state's previous standards for toilet and urinal water use set in 1991 of 1.6 and 1.0 gallons per flush, respectively. On April 8, 2015, in response to the Governor's Emergency Drought Response Executive Order (EO B-29-15), the California Energy Commission approved new standards for urinals requiring that they not consume more than 0.125 gallons per flush, 75% less than the standard set by AB 715.

- Water use standards for residential and commercial clothes washers and dishwashers are established by the U.S. Department of Energy through its authority under the federal Energy Policy and Conservation Act. Water use efficiency is summarized by the water factor for the appliance which measures the gallons of water used per cycle per cubic foot of capacity. A typical top-loading residential clothes washer manufactured in the 1990s had a water factor of about 12 – meaning a typical washer manufactured in that time period used about 12 gallons of water per wash cycle per cubic foot of capacity. Most residential washers have capacities between 3 and 4 cubic feet, so a typical washer manufactured in the 1990s used between 36 and 48 gallons of water per cycle. In 2015, the allowable water factor for top- and front-loading residential clothes was reduced to 8.4 and 4.7, respectively. In 2018, the water factor standard for top-loading residential clothes washers will be reduced to 6.5. In 2010 the allowable water factor for top- and front-loading commercial clothes washers was reduced to 8.5 and 5.5, respectively. The maximum water factor for Energy Star compliant top- and front-loading washers is currently 3.7 and 4.3, respectively. EPA estimates that Energy Star washers comprised at least 60 percent of the residential market and 30 percent of the commercial market in 2011.[4] An Energy Star compliant washer uses about two-thirds less water per cycle than washers manufactured in the 1990s. Federal dishwasher water use efficiency standards were last updated in 2013. The maximum water use for standard and compact sized dishwashers is 5.0 and 3.5 gallons per cycle, respectively.

- New construction and renovations in California are now subject to CalGreen Code requirements. CalGreen includes prescriptive indoor provisions for maximum water consumption of plumbing fixtures and fittings in new and renovated properties. CalGreen also allows for an optional performance path to compliance, which requires an overall aggregate 20% reduction in indoor water use from a calculated baseline using a set of worksheets provided with the CalGreen guidelines. However, regardless of whether a prescriptive or performance path approach is taken to

[4] EPA Energy Star Unit Shipment and Market Penetration Report Calendar Year 2011 Summary.

comply with CalGreen requirements, the state and federal plumbing fixture and appliance efficiency standards described previously establish maximum water use rates for toilets, urinals, showerheads, and clothes washers. New construction and renovated buildings can choose to use fixtures and appliances that are more efficient than required by these standards, but not less efficient.

- SB 407, enacted in 2009, mandates that all buildings in California come up to current State plumbing fixture standards within this decade. This law establishes requirements that residential and commercial property built and available for use on or before January 1, 1994 replace plumbing fixtures that are not water conserving, defined as "noncompliant plumbing fixtures" as follows:
  - any toilet manufactured to use more than 1.6 gallons of water per flush;
  - any urinal manufactured to use more than one gallon of water per flush;
  - any showerhead manufactured to have a flow capacity of more than 2.5 gallons of water per minute; and
  - any interior faucet that emits more than 2.2 gallons of water per minute.

  For single-family residential property, the compliance date is January 1, 2017. For multi-family and commercial property, it is January 1, 2019. In advance of these dates, the law requires effective January 1, 2014 for building alterations and improvements to all residential and commercial property that water-conserving plumbing fixtures replace all noncompliant plumbing fixtures as a condition for issuance of a certificate of final completion and occupancy or final permit approval by the local building department.

- SB 407 also requires effective January 1, 2017 that a seller or transferor of single-family residential property disclose to the purchaser or transferee, in writing, the specified requirements for replacing plumbing fixtures and whether the real property includes noncompliant plumbing. Similar disclosure requirements go into effect for multi-family and commercial transactions January 1, 2019. SB 837, passed in 2011, reinforces the disclosure requirement by amending the statutorily required transfer disclosure statement to include disclosure about whether the property is in compliance with SB 407 requirements. If enforced, these two laws effectively require retrofit of non-compliant plumbing fixtures upon resale or major remodeling for single-family residential properties effective January 1, 2017 and for multi-family and commercial properties effective January 1, 2019.

2.2 SB 407 Implementation

Retrofitting of non-compliant plumbing fixtures is supposed to be completed by January 1, 2017, for single-family residences and by January 1, 2019, for multi-family and commercial buildings. SB 407 relies on local enforcement of its provisions and rates of compliance across counties is unknown and likely to vary significantly. For this study, three scenarios for SB 407 implementation are modeled:

1. No enforcement scenario – Under this scenario, the models assume SB 407 has no impact on the rate of replacement of toilets and urinals. SB 407 is treated as a tiger with no teeth.
2. Retrofit-on-resale scenario – Under this scenario, SB 407 is treated as being equivalent to a statewide retrofit-on-resale requirement. The rate of replacement of non-compliant toilets is accelerated beyond what would be expected through natural replacement of plumbing fixtures alone.
3. Full compliance – Under this scenario, full compliance with SB 407 is assumed.

Scenarios 1 and 3 provide lower- and upper-bounds on the possible impact SB 407 could have on the rate of replacement of non-compliant fixtures. Neither scenario is considered likely. It is already the case that some city and county building departments are conditioning permit approval on replacement of non-compliant fixtures, so some level of enforcement is already occurring. It is also extremely unlikely that full compliance will be achieved by the law's deadlines for compliance. Given the strengthening of the property disclosure requirements under SB 837, whereby a seller or transferor must disclose whether the property is in compliance with SB 407 on the statutorily required disclosure form, the second scenario seems the most plausible. Estimates are provided for each scenario, which in effect provide lower-bound, upper-bound, and most likely estimates of plumbing code impacts on indoor water use.

2.3 Landscape Efficiency Standards

California has also adopted requirements affecting the design and water use of residential and commercial landscaping. Because this study pertains only to the effect of plumbing codes and appliance standards on indoor water use, these requirements are not discussed further in this TM.

2.4 Study Focus is on Toilets, Urinals, and Clothes Washers

Single-family residential indoor water use is distributed among the end uses shown in Table 1. The four primary end uses are toilets, showers, faucets, and clothes washers. Together, they account for 80 percent of residential indoor water use.

Table 1. Distribution of Single-Family Indoor Water Use by End Use

End Use	GPCD	% of Indoor Use
Toilet	14.2	24%
Shower	11.1	19%
Faucet	11.1	19%
Clothes Washer	9.6	16%
Leaks	7.9	13%
Other	2.5	4%
Bath	1.5	3%
Dishwasher	0.7	1%
Total	58.6	100%
Source: Water Research Foundation (2016). Residential End Uses of Water Study, Version 2: Executive Report. Figure 5.		

Plumbing codes and appliance efficiency standards have the potential to impact each of the four main end uses to varying degrees. For this study, the focus was placed on changes in water use for toilets, urinals, and clothes washers, and not on showers and faucets. Even though showers and faucets are significant residential indoor end uses, comprising 38 percent of total indoor water use, end use studies have shown that efficiency standards have had minimal impact on per capita usage rates over the last 15 plus years.[5] For example, whereas single-family per capita water use for toilets and clothes washers decreased by 23 and 36 percent, respectively, between 1999 and 2016, per capita shower and faucet use did not change at all, according to the Water Research Foundation's 2016 Residential End Uses of Water Study.

[5] Water Research Foundation (2016). Residential End Uses of Water, Version 2. PDF Report #4209b.

There are several possible reasons for this. In the case of faucets, one explanation is the nature of the end use. In many instances faucets are used for filling other things, such as pots, kettles, pitchers, glasses, etc. The amount of water used is primarily determined by what is being filled rather than the flow rate of the faucet.[6] In the case of showers, 75 percent of homes met or exceeded showerhead efficiency standards in 1999, leaving little room for further gain.[7] Between then and now, the number of homes with efficient showerheads is estimated to have increased by only 5 percent to 80 percent overall.[8] Compare this to clothes washers which went from 6 percent efficient to 46 percent efficient over the same time period. Likewise toilets, which went from 9 percent efficient to 37 percent efficient.[9] Thus, in the case of showerheads, there may be little further saving to be realized unless showering behavior changes significantly, which the end use studies suggest is not occurring.[10]

This study also did not devote modeling effort to changes in dishwasher water use due to appliance standards. Although the end use studies do show that average per capita water use has decreased by 30 percent between 1999 and 2016, the share of indoor water use for automatic dishwashers is only one percent, as shown in Table 1. Thus, while there may be potential for further efficiency gains for automatic dishwashers, such gains are not expected to have a major impact on overall indoor water use in the way that toilets and clothes washers are.

For these reasons, modeling effort for this study was focused on toilets and clothes washers in the case of residential indoor water use, and toilets, urinals, and clothes washers in the case of non-residential indoor water use.

Even though the empirical evidence to date on shower and faucet use in residential settings does not suggest that plumbing codes for these fixtures have had a significant impact on per capita water use, it is possible they may do so in the future. This may especially be the case for faucets in commercial settings, where there is evidence that non-compliance with existing standards is high.[11] The estimated changes in per capita water use due to plumbing codes and appliance standard presented in this report are therefore conservative. It is more likely they somewhat understate rather than overstate savings potential.

3 Methodology and Data

This study uses dynamic plumbing fixture and appliance inventory growth and replacement models to estimate water use for toilets, urinals, and clothes washers. The models are based on the same methodology used by the Alliance for Water Efficiency's (AWE) Water Conservation Tracking Tool, Version 3, to estimate water savings from plumbing codes and appliance standards.[12] However, unlike

[6] There are obvious exceptions, such as when hot water is used, in which case the water may be left to flow while the water heats up.
[7] Water Research Foundation (2016). Residential End Uses of Water Study, Version 2: Executive Report. Figure 6.
[8] Ibid.
[9] Ibid.
[10] The residential end uses studies measured an average shower duration of 7.8 minutes in both 1999 and 2016. Confidence intervals for these means indicate they are not statistically different. The average number of showers per person per day was 0.66 in 1999 and 0.69 in 2016. Confidence intervals were not provided for these means, but it is unlikely the estimates are statistically different.
[11] City of Santa Cruz (2013).
[12] http://www.allianceforwaterefficiency.org/Tracking-Tool.aspx

the AWE model, which is designed to evaluate individual service areas or an aggregation of multiple service areas, the models for this study are capable of separately estimating fixture and appliance water use for California's 58 counties simultaneously.

The models are implemented in Excel and contained in a single Excel workbook.[13] Separate models are provided for single-family residential, multi-family residential, and non-residential plumbing fixture and appliance inventories and water use. The models operate on an annual time-step that runs through 2040. The starting year is 1990 for the toilet and urinal models and 2005 for the clothes washer models.

3.1 Base Year for Estimating Future Water Savings

Estimating future water savings requires establishing a base year against which changes in water use are measured. This study uses 2015 as the base year. This means that estimated changes in per capita water use over time are based on the difference between estimated future per capita water use and per capita water use in 2015. Aggregate water savings are calculated by multiplying these differences by future population. For example, if toilet water use for single-family households is estimated to be 12 GPCD in 2015 and 8 GPCD in 2030, the expected change in per capita water use between 2015 and 2030 due to improvements in average toilet efficiency is simply 12 - 8, or 4 GPCD. If the population residing in single-family households is projected to be 100,000 in 2030, then the total reduction in single-family residential water use in 2030 because of the improvements in average toilet efficiency since 2015 is simply (12 - 8) x 100,000, or 0.4 million gallons per day (MGD). The annual water savings in 2030 is 0.4 MGD x 365, or 146 million gallons (MG), which is equivalent to 448 acre-feet (AF).

3.2 Model Specifications

In this section, the mathematical structure of the models is presented. Following this, the data and assumptions used to implement the models are described.

3.2.1 Single-Family Residential Toilet Model

The single-family toilet model is a simple inventory growth and replacement model. Despite its simple structure, it nonetheless replicates empirical estimates of average toilet efficiencies quite closely. The model assumes the inventory of toilets using water is governed by the size of the occupied housing stock. The total number of toilets using water is taken as the product of the number of occupied housing units and the average number of toilets per household. Thus projected growth in the stock of toilets is driven by forecasts of growth in occupied housing units.[14]

[13] The underlying methodology could be implemented in other computational platforms, such as R or Mathlab, for example, if there were need to do so.

[14] The models use forecasts of occupied housing units from Department of Finance (DOF). The use of occupied housing units introduces a complication in the fixture water use accounting since at the county level the annual change in the number of occupied housing units can be negative in some years. This may occur because of economic conditions (e.g. the 2007-10 uptick in residential foreclosures) or because some parts of California are estimated to be losing population (e.g. Alpine County). When occupied housing units decrease from one year to another, the model assumes the toilets associated with this decrease are idled. The model keeps a running total of these idled fixtures for each county. If occupied housing subsequently increases, the model first absorbs the idled toilets and associates any residual increase with the installation of new fixtures. This accounting is not shown in the equations presented below because it would significantly complicate the presentation of the model's structure.

The model assumes toilets fall into one of three categories: (1) 3.5+ gallons per flush (gpf) toilets, (2) ULFTs rated 1.6 gpf, and (3) HETs rated 1.28 gpf or less.

The following variables are used to define the relevant quantities in the model:

H_t	Number of occupied housing units in year t
ΔH_t	Change in the number of occupied housing units from t-1 to t
TPH	Average number of toilets per household
P_t	Population in year t
R	Average rate of toilet replacement as a percent of the existing stock
S	Average rate of resale of existing housing units
T_t	Number of toilets of all types in year t
$T_t^{3.5+}$	Number of 3.5+ gpf toilets in year t
T_t^{ULFT}	Number of ULFT toilets in year t
T_t^{HET}	Number of HET toilets in year t
F_t	Average gallons per flush of all toilets in year t
$F^{3.5+}$	Average gallons per flush of 3.5+ gpf toilets
F^{ULFT}	Average gallons per flush of ULFT toilets
F^{HET}	Average gallons per flush of HET toilets
FPD	Average residential flushes per day per person
$GPCD_t^{Toilets}$	Average daily per capita water use for toilet flushing in year t
$W_t^{Toilets}$	Total daily water use for toilet flushing in year t

The inventory of 3.5+ gpf toilets is determined as follows:

$$T_t^{3.5+} = H_t \cdot TPH \qquad t = 1990$$
$$T_t^{3.5+} = T_{t-1}^{3.5+}(1-r) \qquad 1991 \le t < 2017$$

The model assumes all toilets flush at 3.5+ gallons in 1990. This is a simplification since ULFTs were commercially available starting in the 1980s. However, ULFTs had a very low share of residential toilets in 1990, which is safely ignored. Starting in 1991, 3.5+ toilets could no longer be purchased or installed in California.[15] Between 1991 and 2017, the model assumes the inventory of 3.5+ toilets is slowly replaced by ULFTs and HETs. The rate of this replacement is determined by the parameter r.

SB 407 comes into play in 2017. As previously discussed, three scenarios are modeled. Scenario 1 assumes no enforcement, so replacement is treated the same as for the earlier period. Scenario 2 assumes SB 407 acts like a retrofit-on-resale requirement. Replacement of 3.5+ toilets is governed by the parameters r and s.[16] Scenario 3 assumes full compliance. Thus the model assumes all remaining 3.5+ toilets are replaced in 2017.

Scenario 1: No enforcement	$T_t^{3.5+} = T_{t-1}^{3.5+}(1-r)$	$t \ge 2017$
Scenario 2: Retrofit-on-resale	$T_t^{3.5+} = T_{t-1}^{3.5+}(1-s)(1-r)$	$t \ge 2017$
Scenario 3: Full compliance	$T_t^{3.5+} = 0$	$t \ge 2017$

[15] This too is not quite true since California allowed existing inventories of 3.5+ toilets to be liquidated, which meant one could purchase a 3.5+ toilet in 1991 and probably into 1992.

[16] An equivalent way to express the replacement of 3.5+ toilets under the retrofit-on-resale scenario is: $T_t^{3.5+} = T_{t-1}^{3.5+} - rT_{t-1}^{3.5+} - sT_{t-1}^{3.5+} + rsT_{t-1}^{3.5+}$, which says the number of toilets in year t equals the number in year t-1 less the number that are replaced naturally, less the number that are replaced via resale, plus an adjustment so as not to double count toilets as replaced both ways.

The model assumes ULFTs enter the inventory starting in 1991. Between 1991 and 2013 the model assumes all new toilets are ULFTs and when 3.5+ toilets go out of service they are replaced with ULFTs. Starting in 2014, new and replaced toilets must be HET in California. The model assumes the stock of ULFTs is slowly replaced by HETs starting in 2014, as governed by the parameter r.

$$T_t^{ULFT} = 0 \qquad t < 1991$$
$$T_t^{ULFT} = T_{t-1}^{ULFT} + \Delta H_t \times TPH + rT_{t-1}^{3.5+} \qquad 1991 \leq t < 2014$$
$$T_t^{ULFT} = T_{t-1}^{ULFT}(1-r) \qquad t \geq 2014$$

Note that SB 407 does not affect the replacement of ULFTs, since it only requires replacement of a toilet if it has a rated flush volume greater than 1.6 gpf.

HETs enter the model starting in 2014. For the period 2014 to 2016, the growth in HETs is determined by the growth in the housing stock and the natural replacement of 3.5+ and ULFT toilets.

$$T_t^{HET} = 0 \qquad t < 2014$$
$$T_t^{HET} = T_{t-1}^{HET} + \Delta H_t \cdot TPH + r\left(T_{t-1}^{3.5+} + T_{t-1}^{ULFT}\right) \qquad 2014 \leq t \leq 2016$$

Starting in 2017, the inventory of HETs also depends on the SB 407 implementation scenario.

Scenario 1: No enforcement
$$T_t^{HET} = T_{t-1}^{HET} + \Delta H_t \cdot TPH + r\left(T_{t-1}^{3.5+} + T_{t-1}^{ULFT}\right) \qquad t \geq 2017$$

Scenario 2: Retrofit-on-resale
$$T_t^{HET} = T_{t-1}^{HET} + \Delta H_t \cdot TPH + rT_{t-1}^{ULFT} + T_{t-1}^{3.5+}[1-(1-s)(1-r)] \qquad t \geq 2017$$

Scenario 3: Full compliance
$$T_t^{HET} = T_{t-1}^{HET} + \Delta H_t \cdot TPH + rT_{t-1}^{ULFT} + T_{2016}^{3.5+} \qquad t \geq 2017$$

Average flush volume of all toilets in year t is a function of the number of toilets in each category in year t and the average flush volume within the category.

$$F_t = \frac{F^{3.5+} \cdot T_t^{3.5+} + F^{ULFT} \cdot T_t^{ULFT} + F^{HET} \cdot T_t^{HET}}{T_t}$$

Average daily per capita water use for toilets in year t is the product of the average flush volume and the average flushes per person.

$$GPCD_t^{Toilet} = F_t \cdot FPD$$

Total daily water use for toilets in year t is the product of the average daily per capita water use for toilets and the population.

$$W_t^{Toilet} = P_t \cdot GPCD_t^{Toilet}$$

3.2.2 Multi-Family Residential Toilet Model

The multi-family residential toilet model structure is identical to the single-family model. The only difference is SB 407 effects start in 2019 instead of 2017.

3.2.3 Non-Residential Toilet Model

The non-residential toilet model structure is nearly identical to the single- and multi-family residential models. Like the multi-family model, SB 407 effects start in 2019 instead of 2017. The stock of non-residential toilets is also calculated differently. The stock of non-residential toilets in 1992 is taken from the CUWCC CII toilet database. This database estimates the total number of toilets in 1992 by zip code using the methodology outlined in the CUWCC CII ULFT Savings Study (2001). The zip-code level estimates are aggregated to county level. The model then assumes the toilet stock grows at the same rate as county population.

3.2.4 Urinal Model

The urinal inventory model has the same basic structure as the non-residential toilet model. The total number of urinals is assumed to equal one-fourth the inventory of non-residential toilets, per Koeller (2006). Urinals are divided into three categories: (1) 1.0 gpf urinals, (2) 0.5 gpf urinals, and (3) 0.125 gpf urinals. New and replaced urinals are assumed to be 1 gpf between 1990 and 2013, 0.5 gpf in 2014 and 2015, per AB 715, and 0.125 gpf thereafter, per California Energy Commission standards adopted in 2015.

The urinal model does not estimate SB 407 effects. SB 407 requires replacement of any urinal in pre-1994 buildings with a flush rating greater than 1.0 gpf by January 1, 2019. However, estimates of the share of urinals with flush ratings exceeding 1.0 gpf were not available for this study. While there are certainly urinals flushing more than 1.0 gpf in California, their share of the total inventory is believed to be very small and SB 407 effects, could they have been estimated, were not expected to be large.

3.2.5 Residential Clothes Washer Model

The residential clothes washer model, like the residential toilet model, is an inventory growth and replacement model. Because of the different types of clothes washers available to consumers and the phasing of federal clothes washer efficiency standards, it has a somewhat more complicated structure than the residential toilet model.

The model classifies a washer as either conventional or high-efficiency (HEW). HEW washers may be either front-loading (FL) or top-loading (TL). Whether a newly purchased washer is conventional or HEW and FL or TL is governed by market shares used by the model. These market shares change over time and are taken primarily from Department of Energy clothes washer market forecasts (DOE, 2010). The water factor associated with a HEW FL and TL washers is governed by the phasing in of federal clothes washer efficiency standards. These change over time, as discussed in Section 2.

When an existing washer reaching the end of its useful life is replaced, it may be replaced by either a conventional or HEW washer, depending on time-period, market share, and governing efficiency code. The washer may be FL or TL, depending on assumed market share. The model does not assume that FL washers are only replaced by new FL washers and TL washers are replaced only by new TL washers. The mix of FL and TL washers changes over time in the model as a function of the market shares for FL and TL washers.

A washer is an in-unit washer if it is used within an individual housing unit. All single-family washers are treated as in-unit washers. A washer is a common area washer if it is shared by multiple housing units. Most multi-family properties have a mix of in-unit and common area washers. This model pertains only to the water use of in-unit washers. The estimation of water used by common area and commercial coin-op washers is discussed in Section 3.3.6.

The following variables are used to define the relevant quantities in the model:

H_t	Number of occupied housing units in year t
ΔH_t	Change between years t-1 and t in the number of occupied housing units
WPH	Average number of washers per household[17]
COINPCT	Percent of households without washer that use commercial coin-op washers
CAPACITY	Average capacity of a residential clothes washer, in cubic feet
P_t	Population in year t
r	Average rate of washer replacement as a percent of the existing stock
C_t	Number of clothes washers of all types in year t
C_t^{conv}	Number of conventional clothes washers in year t
C_t^{FL}	Number of FL HEW clothes washers in year t
C_t^{TL}	Number of TL HEW clothes washers in year t
M_t^{conv}	Market share of conventional washers in year t
M_t^{FL}	Market share of HEW FL washers in year t
M_t^{TL}	Market share of HEW TL washers in year t
WF_t	Average water factor of all clothes washers in year t
GPL_t	Average gallons per load of laundry in year t
LPD	Average clothes washer loads per day per person
$GPCD_t^{Washer}$	Average daily per capita water use for clothes washers in year t, in gallons
W_t^{Washer}	Total daily water use for clothes washers in year t, in gallons

$C_t \equiv C_t^{conv} + C_t^{FL} + C_t^{TL}$ and $M_t^{conv} + M_t^{FL} + M_t^{TL} \equiv 1$

The number of conventional washers in year t is equal to the number of conventional washers in year t-1 that do not fail plus the number of washers of all types in year t-1 that fail and are replaced with conventional washers plus the number of new conventional washers.[18]

$$C_t^{conv} = C_{t-1}^{conv} \cdot (1-r) + r \cdot C_{t-1} \cdot M_t^{conv} + \Delta H_t \cdot WPH \cdot M_t^{conv}$$

Similarly, the number of HEW FL (TL) washers in year t is equal to the number of HEW FL (TL) washers in year t-1 that do not fail plus the number of washers of all types in year t-1 that fail and are replaced with HEW FL (TL) washers plus the number of new HEW FL (TL) washers.[19]

$$C_t^{FL} = C_{t-1}^{FL} \cdot (1-r) + r \cdot C_{t-1} \cdot M_t^{FL} + \Delta H_t \cdot WPH \cdot M_t^{FL}$$

$$C_t^{TL} = C_{t-1}^{TL} \cdot (1-r) + r \cdot C_{t-1} \cdot M_t^{TL} + \Delta H_t \cdot WPH \cdot M_t^{TL}$$

[17] This is a number between 0 and 1 and represents the rate of ownership of washers. For example, a WPH of 0.95 indicates that 95 percent of households have a clothes washer.

[18] As with toilets, because the model uses estimates and projections of occupied housing units, it is possible to have a negative change in occupied housing units from one year to another. In this case the clothes washers associated with these housing units are assumed to be removed from the inventory of all clothes washers. Unlike for toilets, the model does not assume these removed washers come back into the inventory later. If a subsequent change in occupied housing units is positive, the model assumes new washers are acquired for these housing units. This assumption is made because clothes washers are portable and are often relocated when a household moves to a new location. Thus the model assumes that if households leave a region, they take their washers with them. Obviously, this will not always be the case, especially in the case of rented properties, but the model assumes it is more likely than not to be the case.

[19] Note that adding these three equations together yields the identity that the number of washers of all types in year t equals the number of washers of all types in year t-1 plus the number of washers of all types in new homes.

The model assumes the average water factor of conventional washers is 11 in all time periods. The average water factor of new FL and TL washers varies over time. In the starting year of 2005, the FL and TL average water factors of the existing stock of HEW washers are assumed to be 7.0 and 8.5, respectively. These values were selected to calibrate the model to the average water use of HEW and conventional washers circa 2005 based on end use study results. The average water factor of new FL washers is assumed to be 6.0 for the period 2005 to 2014 and 4.5 thereafter. The average water factor for new TL washers is assumed to be 8.0 for the period 2005 to 2017 and 6.0 thereafter. Thus, the washer inventory is allocated into six water factor categories:

1. WF 11.0 – average water factor of conventional washers
2. WF 8.5 – average water factor of HEW TL washers purchased prior to 2005
3. WF 8.0 – average water factor of HEW TL washers purchased between 2005 and 2017
4. WF 7.0 – average water factor of HEW FL washers purchased prior to 2005
5. WF 6.0 – average water factor of HEW TL washers purchased after 2017 and HEW FL washers purchased between 2005 and 2014
6. WF 4.5 – average water factor of HEW FL washers purchased after 2014

The model allocates new washers to these water factor categories depending on time period and whether the new washer is conventional, FL, or TL. The number of washers in each category that fail each year is governed by the replacement parameter, r. Through these two processes, the model maintains a running total of active washers in each of the six categories.

Let i = 1,…,6 be the index of water factor categories, the average water factor for the stock of washers in year t is:

$WF_t = \sum_{i=1}^{6} \frac{WF_i \cdot C_t^{WF_i}}{C_t}$, where $C_t^{WF_i}$ is the number of washers in WF category i in year t.

The average water use per load of laundry in gallons in year t is:

$$GPL_t = WF_t \cdot CAPACITY$$

Total daily water use for in-unit clothes washers in year t is the product of the average gallons per load and the daily number of loads. The daily number of loads is equal to the product of the fraction of households with clothes washers, the population, and the average loads per person per day in homes with clothes washers.

$$W_t^{Washer} = GPL_t \cdot WPH \cdot P_t \cdot LPD$$

The average daily water use per person for in-unit clothes washers in year t is equal to total daily water use by in-unit clothes washers divided by the population using in-unit clothes washers. This is the same as gallons per load multiplied by loads per day per person:

$$GPCD_t^{Washer} = GPL_t \cdot LPD$$

3.2.6 Multi-family Common Area and Commercial Coin-Op Clothes Washer Water Use

Data on the number of multi-family common area and commercial coin-op clothes washers in California is scant. This study did not attempt to directly estimate this category of water use with an inventory growth and replacement model. Instead, the study approximates the annual water use by multi-family common area and commercial coin-op clothes washers by assuming that the single- and multi-family residential population without in-unit clothes washers would use a similar amount of water for clothes washing on a per capita basis as the population with in-unit washers.[20] Under this assumption, the GPCD for common area and coin-op clothes washers is assumed to be the same as shown above and the total daily water use for these washers is estimated as:

$$W_t^{CommonWasher} = GPL_t \cdot (1 - WPH) \cdot (1 - COINPCT) \cdot P_t \cdot LPD$$

$$W_t^{CoinOpWasher} = GPL_t \cdot (1 - WPH) \cdot COINPCT \cdot P_t \cdot LPD$$

3.3 Data and Assumptions

In this section, the data and assumptions used to implement the toilet, urinal, and clothes washer models are reviewed.

3.3.1 County Population and Housing Estimates

Historical and projected occupied housing units for single- and multi-family residences come from the following sources:

- 1990-2010: DOF E-8 Historical Population and Housing Estimates
- 2011-2015: DOF E-5 Population and Housing Estimates
- 2016-2030: DOF P-4 Projected Households. DOF projections are in 5-year increments. Linear interpolation is used for years between the DOF projections. The DOF projections are for total households. Single-family households are estimated by multiplying total households by the ratio of single-family to total households in 2015.[21] Multi-family households are estimated as the residual between total households and single-family households.
- 2031-2040: Total households are estimated from DOF P-1 population projection scaled by the ratio of household to total population in 2030 (from DOF P-4) and then divided by the average persons per household in 2030. Single-family households are estimated by multiplying total households by the ratio of single-family to total households in 2015. Multi-family households are estimated as the residual between total households and single-family households. DOF population projections are in 5-year increments. Linear interpolation is used for years between the DOF projections.

Historical and projected total and household population comes from the following sources:

- 1990-2010: DOF E-8 Historical Population and Housing Estimates
- 2011-2015: DOF E-5 Population and Housing Estimates
- 2016-2030: DOF P-4 State and County Projected Households, Household Population, Group Quarters, and Persons per Household. DOF projections are in 5-year increments. Linear interpolation is used for years between the DOF projections.

[20] This is likely to somewhat overstate water use by common area and commercial coin-op washers for at least two reasons. First, households using common area and coin-op washers may use washers less frequently because of the time, inconvenience, and expense involved. Second, common area and commercial washers may be more efficient, on average, than residential washers because they typically have larger capacities and are changed out more frequently.

[21] The share of single-family households as a share of total households was estimated for each year in the period 1990-2015 and found to be very stable for most counties.

- 2031-2040: DOF P-1 Total Population Projections for California and Counties. DOF projections are in 5-year increments. Linear interpolation is used for years between the DOF projections. Household population is calculated by multiplying the DOF P-1 projections by the ratio of household to total population in 2030 from DOF P-4.

Historical and projected average persons per households (PPH) comes from the following sources:

- PPH for total housing units is calculated by dividing total household population by total housing units.
- PPH for single-family housing units is calculated as follows: Let ρ be the county's ratio of single-family to multi-family PPH calculated from Census 2000 data, P_t be total household population, SFR_t be total single-family housing units, and MFR_t be total multi-family housing units, then

$$PPH_t^{SFR} = P_t/(SFR_t + \rho MFR_t)$$

- PPH for multi-family housing units is calculated as:

$$PPH_t^{MFR} = P_t/\left(MFR_t + \frac{1}{\rho}SFR_t\right)$$

Historical and projected population in single- and multi-family housing is calculated by multiplying the housing units in each category of its respective estimate of PPH.

3.3.2 Average Toilets and Clothes Washers per Household

The average number of toilets and clothes washers per household in single- and multi-family housing units are estimated from the 2011 American Housing Survey Public Use Micro Sample Data for the eight SMSAs in the data file located in California. County-level estimates are set to the estimates for the most proximate SMSA. The estimates are provided in Attachment 1.

3.3.3 Common Area and Coin-Op Washer Usage Rates

Households that do not have an in-unit washer are assumed to do their washing at an on premise common area washing room or at an off premise commercial coin-op laundry. All single-family households without washers are assumed to use off premise commercial coin-op laundries. Seventy-two percent of multi-family households without in-unit washers are assumed to use on premise common area washers and 28 percent are assumed to use off premise commercial coin-op laundries. The assumptions for multi-family are based on results of a 2013 survey of multi-family renters conducted by the Coin Laundry Association.[22]

3.3.4 Average Residential Clothes Washer Capacity

The clothes washer models assume in-unit clothes washers have an average capacity of 3.5 cubic feet.

3.3.5 Average Daily Toilet, Urinal, and Clothes Washer Usage

A resident of a household is assumed to flush toilets in the household an average of 5 times per day. This value is taken from the 2016 Residential End Uses of Water Study.

[22] http://www.coinlaundry.org/blogs/bob-nieman/2015/01/26/taking-a-new-route

Households with washers are assumed to do an average of 0.31 loads of laundry per person per day. This value is the average of the usage rates reported in the 1999, 2010, and 2016 Residential End Uses of Water Studies.

The non-residential toilet model estimates an average toilet flush rate for each county based on water savings estimates from the CUWCC CII ULFT Savings Study (2001). The average flush rate for a county is calculated as the weighted average flush rate across ten end-use categories: hotels, health services, offices, retail/wholesale, industrial, government, schools, and other. The flush rate for each category is calculated by dividing the estimated daily water savings from replacing a 3.5+ gpf toilet with a ULFT toilet in this category by the assumed difference in flush volumes between the replaced toilet and the ULFT. For this calculation it was assumed the replaced toilet had an average flush volume of 3.85 gpf and the replacement ULFT had and average flush volume of 1.9 gpf. The estimated average daily flush rates for non-residential toilets by county are provided in Attachment 2.

Data on flush rates of non-residential urinals is scant. The model estimates urinal water use using the approach suggested by Vickers (2001), which bases it on the level of male employment in a region. Vickers (2001) reports an average usage of two flushes per day per male worker. Total daily urinal flushes in the model is therefore equal to twice the level of male employment. Male employment is assumed to equal 53 percent of county employment.[23] This yields an average daily flush rate of about 28 flushes per urinal statewide. Note the model does not attempt to estimate urinal water use by non-workers in restaurants, bars, and other public spaces. Therefore, the model likely provides a conservative estimate of urinal water use.

3.3.6 Average Toilet Water Use by Toilet Category

The toilet replacement models assume the following average water use per flush by toilet category:

Toilet Category	Average Use per Flush (gal)
3.5+	3.85
ULFT	1.90
HET	1.30

These amounts are based on the distribution of toilet flush volumes reported in the 2016 Residential End Uses of Water Study.

3.3.7 Toilet and Clothes Washer Replacement Rates

The toilet and clothes washer annual replacement rates used in the models are 4.0 and 7.1 percent, respectively. These rates are equivalent to average useful lives of 25 and 14 years, respectively. A 25-year average useful life for toilets is a standard assumption and empirical estimates from plumbing fixture saturation studies have confirmed its reasonableness. A 14-year average useful life for residential clothes washers is based on clothes washer industry estimates.

3.3.8 Clothes Washer Market Shares

Market shares for conventional, HEW TL, and HEW FL clothes washers are based on Department of Energy market assessments developed during its energy and water efficiency standards setting for residential clothes washers. These shares are shown in Table 2.

[23] Based on BLS employment data for California.

Table 2. Clothes Washer Market Share Assumptions

Year	Conventional	HEW FL	HEW TL
2006	50%	10%	40%
2007	45%	17%	39%
2008	35%	26%	39%
2009	25%	38%	38%
2010	15%	51%	34%
2011	10%	54%	36%
2012	10%	54%	36%
2013	10%	54%	36%
2014	10%	54%	36%
2015-2040	0%	60%	40%

3.3.9 Property Resale Rates

Long-term average property resale rates are used in the toilet models to estimate SB 407 toilet replacement effects under Scenario 2 where SB 407 is modeled as equivalent to a retrofit-on-resale requirement. Average resale rates for single- and multi-family housing units by hydrologic region for the period 1990-1998 are used to estimate the long-run average resale rates of residential housing units in the models. The resale data was originally developed by Dataquick for the CUWCC in the early 2000s when CUWCC was modeling residential retrofit-on-resale water savings for toilet, faucet, and showerhead programs. Estimates of commercial property resale rates were not available for this study. For purposes of estimating SB 407 effects under Scenario 2, the non-residential toilet model assumes commercial resale rates are the same as for the multi-family sector. The property resale rates assumed for each county are provided in Attachment 1.

4 Model Results and Comparisons to Empirical Benchmarks

In this section, model results are compared to empirical estimates of average fixture water use, where such estimates are available.

4.1 Model Estimates of Average Water Use

Model estimates of historical average water use for toilets and washers are given in Table 3. Toilet estimates span the period 1990-2015. Clothes washer estimates span the period 2005-2015. The estimates in Table 3 are statewide averages.

Table 3. Model Estimates of Average Water Use by Plumbing Fixture

	Toilets (gal/flush)			Urinals (gal/flush)	Clothes Washers (gal/load)	
Year	**SFR**	**MFR**	**Non-Res**	**Non-Res**	**SFR**	**MFR**
1990	3.85	3.85	3.85	1.00		
1991	3.74	3.75	3.75	1.00		
1992	3.65	3.65	3.65	1.00		
1993	3.56	3.57	3.55	1.00		
1994	3.47	3.50	3.48	1.00		
1995	3.39	3.43	3.40	1.00		
1996	3.32	3.37	3.33	1.00		
1997	3.24	3.31	3.26	1.00		
1998	3.18	3.25	3.19	1.00		
1999	3.11	3.19	3.12	1.00		
2000	3.04	3.13	3.05	1.00		
2001	2.99	3.08	2.99	1.00		
2002	2.93	3.02	2.93	1.00		
2003	2.88	2.97	2.88	1.00		
2004	2.83	2.92	2.83	1.00		
2005	2.78	2.87	2.79	1.00	35.7	35.7
2006	2.73	2.83	2.75	1.00	35.4	35.4
2007	2.69	2.78	2.71	1.00	35.0	35.0
2008	2.65	2.74	2.67	1.00	34.6	34.6
2009	2.62	2.70	2.64	1.00	34.0	34.0
2010	2.59	2.67	2.60	1.00	33.4	33.4
2011	2.56	2.63	2.57	1.00	32.8	32.8
2012	2.53	2.60	2.54	1.00	32.3	32.2
2013	2.50	2.57	2.50	1.00	31.7	31.7
2014	2.45	2.50	2.45	0.98	31.2	31.2
2015	2.40	2.45	2.39	0.95	30.5	30.3

4.2 End Use Studies and Benchmarks

Results from three separate water end-use studies of single-family households spanning a 17 year period are used as benchmarks for assessing residential toilet and clothes washer model performance. The end-use study benchmarks are based on data-logging that records end-use events and associated water volumes for samples of single-family households. The first end-use study, published in 1999, sampled households throughout North America, including California. The second study, published in 2011, was specific to California. The third study, published in 2016, sampled households outside of

California.[24] The 1999 study measured household water end-uses over the period 1996-98. The 2011 study measured water end-uses over the period 2005-08. The 2016 study measured household water end-uses over the period 2012-13.

Comparison of model results to end-use benchmarks is limited to the single-family sector models. While water end-uses of multi-family and commercial sectors have been studied to a limited extent, the sample sizes in these studies are small and the results are not sufficiently general to provide reliable benchmarks.

Because data logging for each end-use study spanned multiple years, the model results are averaged over the data logging period before they are compared to the end-use benchmark. For example, the 2016 study benchmarks are compared to the average model results for 2012-13 because data logging took place in 2012 and 2013.

4.2.1 Single-Family Toilet Benchmark Comparison

Table 4 compares the single-family toilet model estimates of average toilet water use per flush to the end-use study benchmarks. In the case of the 1999 end use study, the benchmark is calculated from the sample of households located in California only. The 2011 study benchmark is also based only on California homes. The 2016 study did not include California homes in the data-logging sample. It is expected that average toilet water use measured in the 2016 study would be somewhat higher than for California, which mandated ULFTs sooner and has made significant investments in toilet replacement programs.

The model estimates are within +/- 2.5 percent of the three end use study benchmarks. As expected, the model's estimate is somewhat less than the 2016 study benchmark, which is based on toilets in homes outside of California. The 2011 end-use study benchmark, which is based on the largest sample of California homes of the three end-use studies, shows the closest correspondence with the model estimate, differing by less than 2 percent. Despite the simple structure of the toilet inventory growth and replacement model, it provides a close correspondence with available empirical benchmarks of average toilet water use.

Table 4. Comparison of Single-Family Toilet Model Results to End-Use Study Benchmarks

End Use Study Publish Year	Data Logging Period	End Use Study Benchmark (gal/flush)	Model Estimate (gal/flush)	% Diff
2016	2012-13	2.58	2.51	-2.5%
2011	2005-08	2.76	2.71	-1.8%
1999	1996-98	3.17	3.25	2.4%
Notes: the 1999 and 2011 benchmarks are based on homes in California. The 2016 benchmark is based on homes outside of California.				

[24] Households were sampled in six locations: Denver CO, Fort Collins CO, San Antonio TX, Scottsdale AZ, Clayton County GA, Tacoma WA, and the City of Waterloo and the Peel Region in Southern Ontario.

4.2.2 Single-Family Clothes Washer Benchmark Comparison

Table 5 compares the single-family clothes washer model estimates of average water use per load to the end-use study benchmarks. The model estimates are within +/- 3.2 percent of the two relevant end use study benchmarks. As with the single-family toilet model, the washer model replicates the end-use study benchmarks fairly closely, despite its simple structure.

Table 5. Comparison of Single-Family Clothes Washer Model Results to End-Use Study Benchmarks

End Use Study Publish Year	Data Logging Period	End Use Study Benchmark (gal/load)	Model Estimate (gal/load)	% Diff
2016	2012-13	31.0	32.0	3.2%
2011	2005-08	36.0	35.2	-2.4%
Notes: the 2011 benchmark is based on homes in California. The 2016 benchmark is based on homes outside of California.				

5 Projected Water Savings

In this section, projected effects of plumbing codes and appliance standards on total M&I water demand and GPCD are presented. The statewide effects are presented here and the county-level effects are presented in Attachment 3. As discussed above, all savings effects are measured relative to a 2015 baseline efficiency level.

5.1 Single-Family Sector

Table 6 summarizes the projected effects of plumbing codes and appliance standards on single-family water use under SB 407 scenario 2. Aggregate water savings are projected to reach about 291 TAF in 2040. Approximately 60 percent of the savings is associated with toilet plumbing codes and 40 percent with clothes washer efficiency standards. Relative to the 2015 baseline, single-family per capita demand is reduced by 7.6 GPCD by 2040. County-level GPCD effects vary, with a minimum 2040 reduction of 6.7 GPCD and a maximum reduction of 8.6 GPCD (see Attachment 3 for county-level estimates).

Table 7 summarizes the projected statewide effects for each SB 407 scenario. Recall that scenario 1 assumes SB 407 has no impact on toilet replacement, scenario 2 assumes it has the same effect as a retrofit-on-resale requirement, and scenario 3 assumes it achieves full compliance within its stated deadlines.

In the long-run, there is not much difference in model results between scenarios 2 and 3. It is a question of timing. Assuming full compliance by the stated deadlines of SB 407 has a significant impact on single-family residential water use in the near-term. The GPCD reduction in 2020 under scenario 3 is 79 percent greater than under scenario 2. By 2030, the differential has decreased to 15 percent, and by 2040, it is only 5 percent. As discussed in Section 3.2, scenarios 1 and 3 bound the potential effect of SB 407 on residential water use, but neither scenario is considered very likely. Scenario 2 is believed to provide the best estimate of potential SB 407 effects on single-family water use.

Projected rates of fixture saturation for single-family toilets and clothes washers are shown in Figures 1-3. Figure 2 shows the division of clothes washers between conventional and high-efficiency categories. Figure 3 shows a more detailed break-down by water factor. Clothes washers with a water factor of 11 are classified in the model as conventional washers. All figures are based on SB 407 implementation scenario 2.

Table 6. Statewide Effect of Plumbing Codes and Appliance Standards on Single-Family Water Use: SB 407 scenario 2

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Single-Family Population	29,298,916	30,611,455	31,908,231	33,159,820	34,286,582
Water Savings (AF)					
Toilets	57,325	99,271	130,939	155,365	174,208
Clothes Washers	38,418	67,327	88,795	105,016	117,237
Total	95,743	166,598	219,735	260,381	291,445
GPCD Reduction					
Toilets	1.7	2.9	3.7	4.2	4.5
Clothes Washers	1.2	2.0	2.5	2.8	3.1
Total	2.9	4.9	6.1	7.0	7.6
County Range of Total GPCD Reduction					
Min	2.7	4.4	5.5	6.2	6.7
Max	4.0	6.2	7.4	8.1	8.6

Table 7. Statewide Effect of Plumbing Codes and Appliance Standards on Single-Family Water Use by SB 407 Scenario

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Total Savings (AF)					
SB 407 Scenario					
1	82,200	144,087	193,776	234,175	266,734
2	95,743	166,598	219,735	260,381	291,445
3	171,435	216,870	253,131	282,568	306,189
GPCD Reduction					
SB 407 Scenario					
1	2.5	4.2	5.4	6.3	6.9
2	2.9	4.9	6.1	7.0	7.6
3	5.2	6.3	7.1	7.6	8.0

Figure 1. Projected Percent of Single-Family Toilet Inventory by Toilet Type

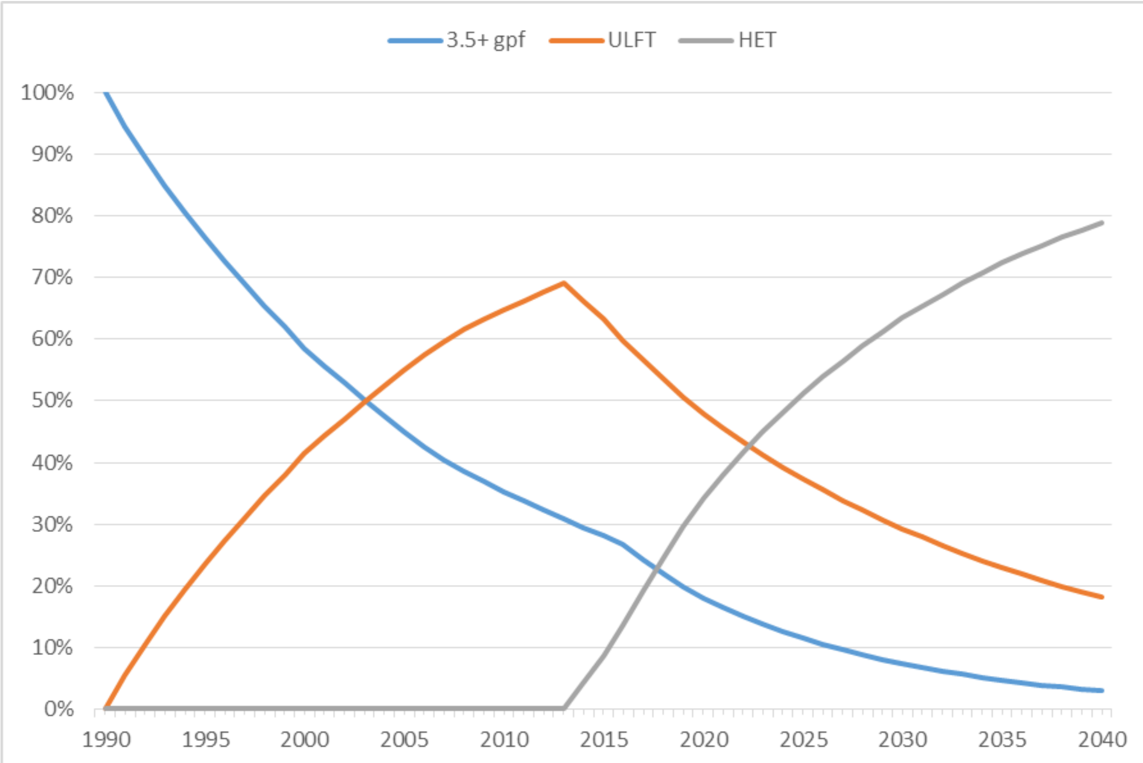


Figure 2. Projected Percent of Conventional and HEW Single-Family Clothes Washers

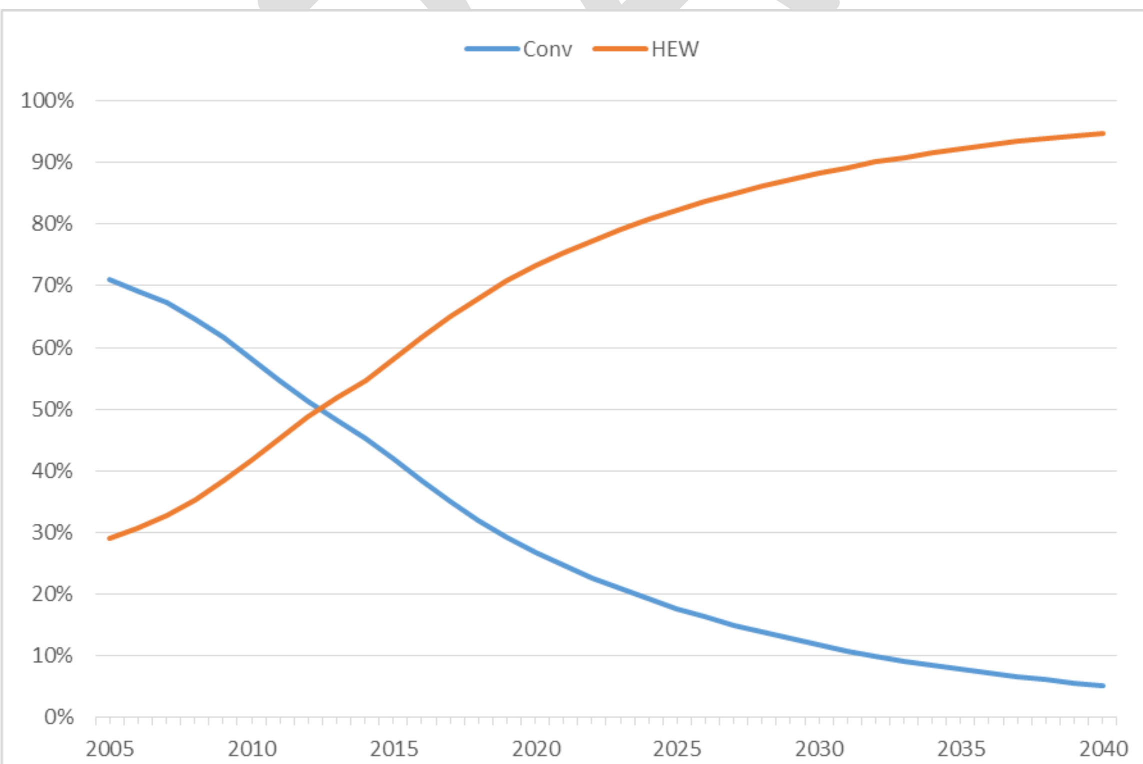
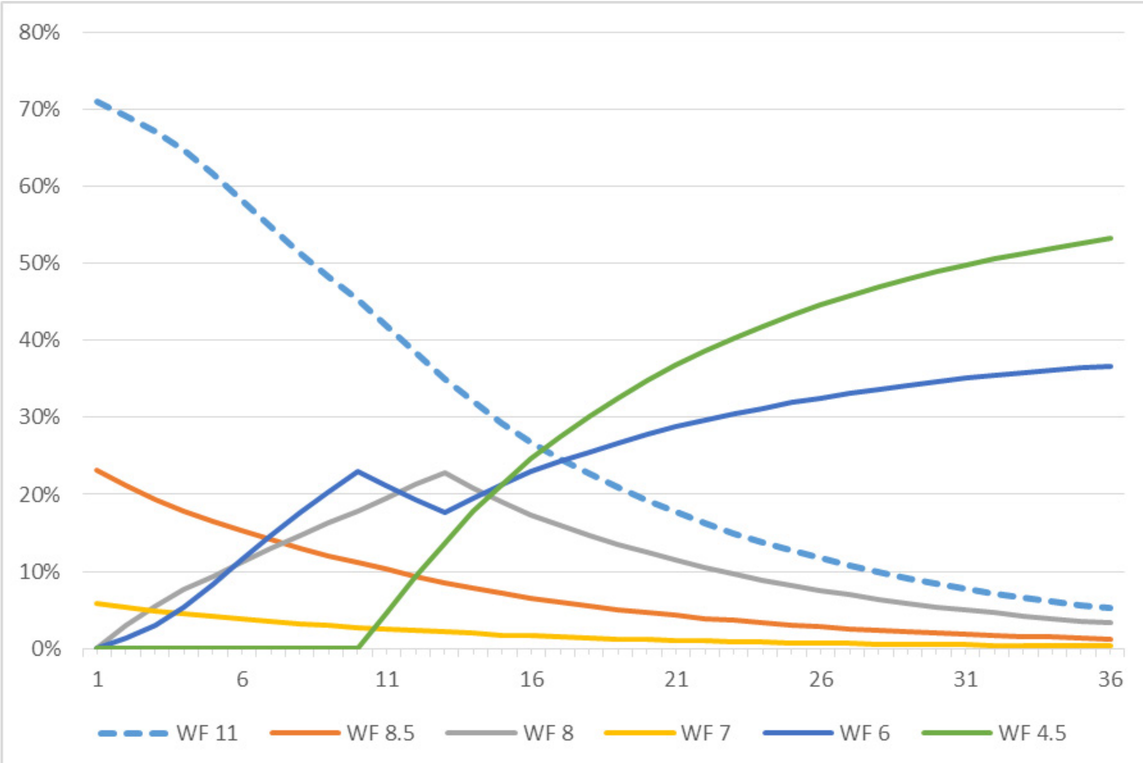


Figure 3. Projected Percent of Single-Family Clothes Washers by Water Factor



5.2 Multi-Family Sector

Table 8 summarize the statewide projections for the multi-family sector. Aggregate water savings are projected to reach just over 100 TAF in 2040. Approximately 64 percent of the savings is associated with toilet plumbing codes and 36 percent with clothes washer efficiency standards. Relative to the 2015 baseline, multi-family per capita demand is reduced by 7.5 GPCD by 2040. County-level GPCD effects vary, with a minimum 2040 reduction of 6.2 GPCD and a maximum reduction of 8.0 GPCD (see Attachment 3 for county-level estimates).

Table 9 summarizes the projected statewide effects for each SB 407 scenario. Aggregate water savings in 2040 range between 90 and 105 TAF. Per capita water savings in 2040 range between 6.7 and 7.9 GPCD. As with single-family, the SB 407 compliance assumption primarily affects the timing of the savings. In 2020, scenario 3 savings are double scenario 2 savings. By 2040, they differ by just five percent.

Projected rates of fixture saturation for multi-family toilets and clothes washers are shown in Figures 4-6. Figure 5 shows the division of clothes washers between conventional and high-efficiency categories. Figure 6 shows a more detailed break-down by water factor. Clothes washers with a water factor of 11 are classified in the model as conventional washers. All figures are based on SB 407 implementation scenario 2.

Table 8. Statewide Effect of Plumbing Codes and Appliance Standards on Multi-Family Water Use: SB 407 scenario 2

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Single-Family Population	10,451,798	10,848,737	11,228,510	11,587,861	11,913,514
Water Savings (AF)					
Toilets	19,523	36,830	49,002	57,818	64,337
Clothes Washers	11,970	20,930	27,486	32,347	35,972
Total	31,493	57,760	76,488	90,165	100,309
GPCD Reduction					
Toilets	1.7	3.0	3.9	4.5	4.8
Clothes Washers	1.0	1.7	2.2	2.5	2.7
Total	2.7	4.8	6.1	6.9	7.5
County Range of Total GPCD Reduction					
Min	2.3	4.0	5.1	5.8	6.2
Max	3.2	5.5	6.7	7.4	8.0

Table 9. Statewide Effect of Plumbing Codes and Appliance Standards on Multi-Family Water Use by SB 407 Scenario

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Total Savings (AF)					
SB 407 Scenario					
1	27,906	48,806	65,470	78,883	89,686
2	31,493	57,760	76,488	90,165	100,309
3	63,088	77,508	88,873	97,965	105,245
GPCD Reduction					
SB 407 Scenario					
1	2.4	4.0	5.2	6.1	6.7
2	2.7	4.8	6.1	6.9	7.5
3	5.4	6.4	7.1	7.5	7.9

Figure 4. Projected Percent of Multi-Family Toilet Inventory by Toilet Type

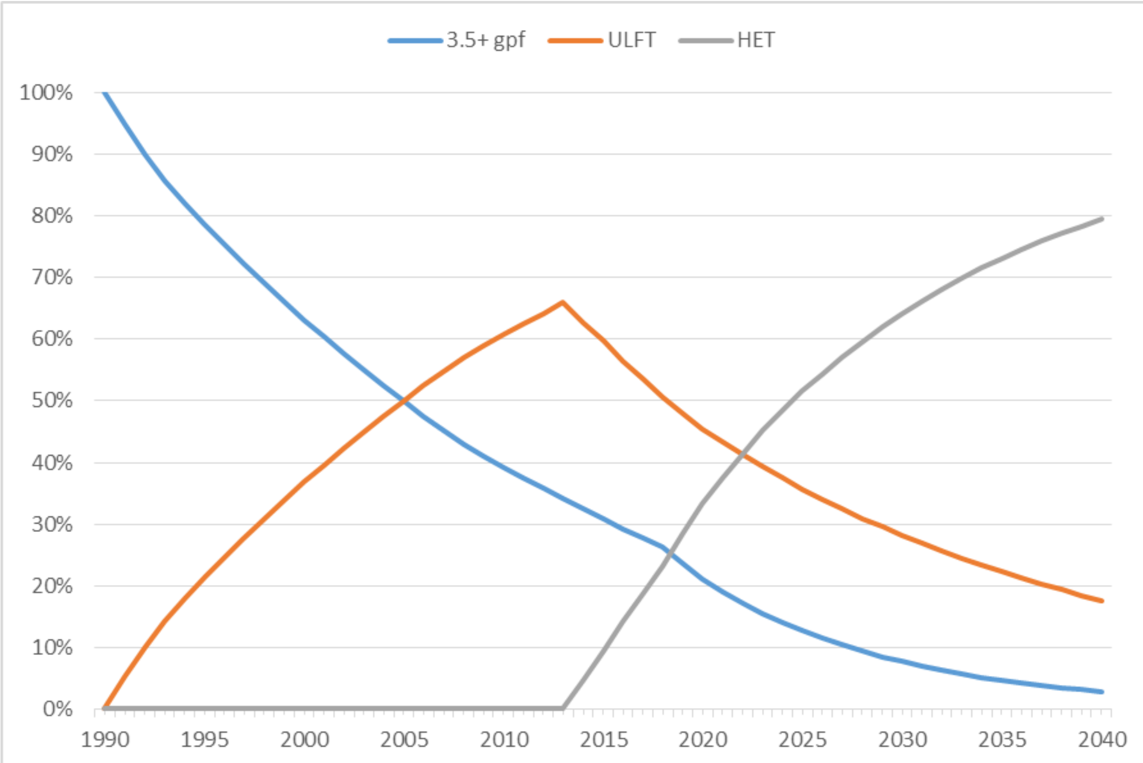


Figure 5. Projected Percent of Conventional and HEW Multi-Family Clothes Washers

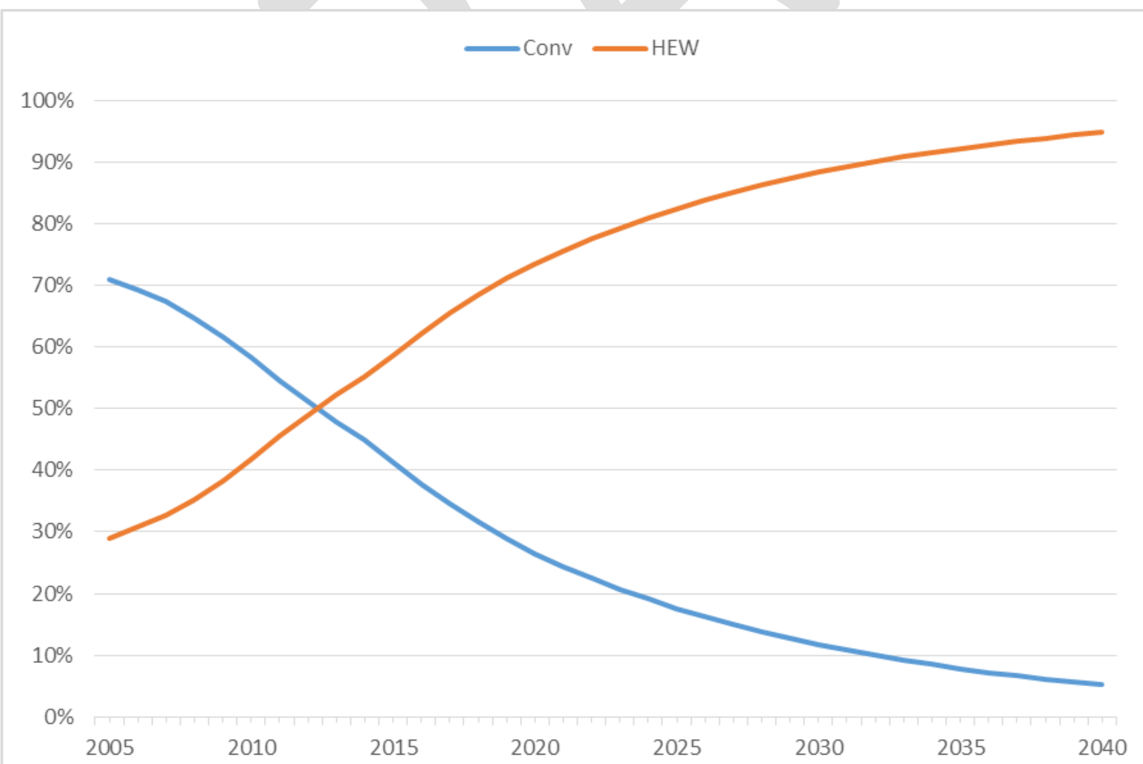
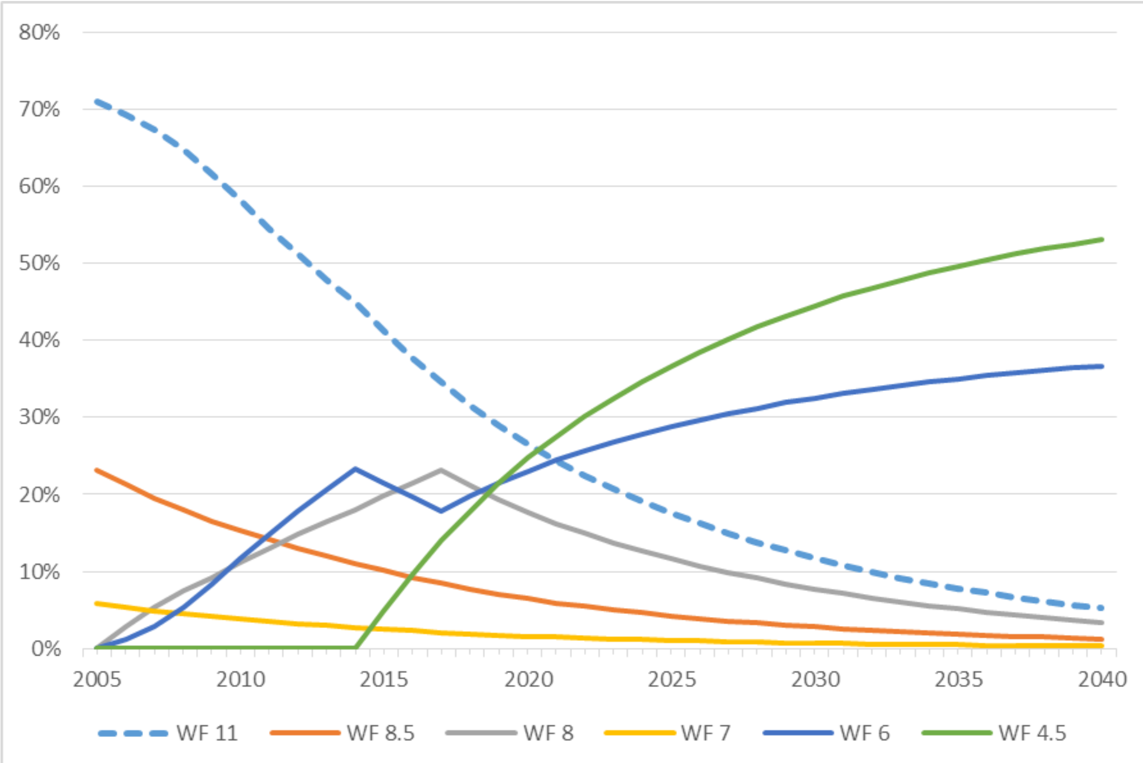


Figure 6. Projected Percent of Multi-Family Clothes Washers by Water Factor



5.3 Combined Residential and Non-Residential Sectors

Table 10 summarizes the total estimated statewide effects of plumbing codes and appliance standards. These effects are based on changes in residential toilet and clothes washer water use discussed in the previous two sections, plus non-residential water use for coin-op clothes, toilets, and urinals.

Note that the GPCD reduction estimates presented in this section are based on total population, which includes population in both households and group quarters. In Section 5.2, the GPCD estimates were calculated using the single-family household population, and in Section 5.3, they were calculated using the multi-family population. Thus, it is important to be mindful that each section is using a different population in the denominator of the GPCD calculation and therefore the GPCD estimates in these three sections cannot be directly compared.

Aggregate water savings are projected to reach more than 512 TAF in 2040 under SB 407 scenario 2. Approximately two-thirds of the savings is associated with toilet/urinal plumbing codes and one-third with clothes washer efficiency standards. Relative to the 2015 baseline, M&I per capita demand is reduced by 9.7 GPCD by 2040. County-level GPCD effects vary, with a minimum 2040 reduction of 7.4 GPCD and a maximum reduction of 12.4 GPCD (see Attachment 3 for county-level estimates).

As with the single- and multi-family results, the effect of the SB 407 scenario, as shown in Table 11, is primarily one of timing. In the long-run, the differences between the three scenarios are not large, but in the near-term they are. For the reasons discussed in Section 3.2, scenario 2 is believed to provide the best estimate of the future effect of SB 407 on M&I water use.

Table 10. Statewide Effect of Plumbing Codes and Appliance Standards on M&I Water Use: SB 407 scenario 2

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Total Population	40,616,702	42,373,655	44,099,585	45,747,645	47,233,240
Water Savings (AF)					
Toilets & Urinals	104,687	190,218	253,626	301,817	338,745
Clothes Washers 1/	57,187	100,163	131,938	155,812	173,741
Total	161,874	290,381	385,563	457,630	512,486
GPCD Reduction					
Toilets & Urinals	2.3	4.0	5.1	5.9	6.4
Clothes Washers 1/	1.3	2.1	2.7	3.0	3.3
Total	3.6	6.1	7.8	8.9	9.7
County Range of Total GPCD Reduction					
Min	2.8	4.7	6.0	6.8	7.4
Max	5.4	8.8	10.7	11.7	12.4
1/ Includes savings from in-unit residential, common area, and coin-op washers.					

Table 11. Statewide Effect of Plumbing Codes and Appliance Standards on M&I Water Use by SB 407 Scenario

Year	**2020**	**2025**	**2030**	**2035**	**2040**
Total Savings (AF)					
SB 407 Scenario					
1	140,824	249,119	336,509	407,756	465,476
2	161,874	290,381	385,563	457,630	512,486
3	304,661	382,748	445,478	496,603	537,912
GPCD Reduction					
SB 407 Scenario					
1	3.1	5.2	6.8	8.0	8.8
2	3.6	6.1	7.8	8.9	9.7
3	6.7	8.1	9.0	9.7	10.2

5.4 Projected Reduction in R-GPCD

More than three-quarters of the projected reduction in water use is expected to occur in the single- and multi-family residential sectors. Data on residential per capita water use (R-GPCD) is collected by the

State Water Board on a monthly basis. During the current drought, the State Water Board used R-GPCD as the basis for setting water supplier conservation targets.

Indoor R-GPCD currently averages about 59 gallons per day.[25] By 2040, plumbing codes and appliance standards are projected to reduce indoor R-GPCD by 7.6 gallons, or about 13 percent of current indoor R-GPCD. The expected change in indoor R-GPCD by year is shown in Table 12. Estimated reductions in R-GPCD by county are provided in Attachment 4 and discussed in the next section.

Indoor single-family residential water use in new homes fitted with EPA WaterSense labeled products averages 36 GPCD (DeOreo, et al., 2011). The difference in indoor water use between the average residence in California and such a home is about 23 GPCD. Plumbing codes and appliance standards on their own are projected to reduce this difference by a third to 15 GPCD by 2040.

Table 12. Change in 2015 Baseline Indoor R-GPCD Due to Plumbing Codes and Appliance Standards

Year	**2020**	**2025**	**2030**	**2035**	**2040**
2015 Baseline Indoor R-GPCD	58.6	58.6	58.6	58.6	58.6
Reduction Due to Codes and Standards	2.9	4.8	6.1	7.0	7.6
Indoor R-GPCD After Adjusting for Codes and Standards	55.7	53.8	52.5	51.6	51.0
% Reduction from 2015 Baseline	5%	8%	10%	12%	13%

5.5 Geographic Variability in Projected R-GPCD Reduction

Projected savings vary to some degree by county. These differences are driven by differences in the age of the housing stock, the projected rate of growth in the county, and, for SB 407 scenario 2, the rate of property resale.

5.5.1 Effect of Housing Stock Age on Project Water Savings

Housing stock age has a significant effect on projected water savings for toilets. Figure 7 plots the projected reduction in R-GPCD from toilet standards against the percent of a county's 2014 housing stock constructed before 1990.[26] Projected savings are positively correlated with housing stock age. Toilet standards are projected to have a bigger effect on R-GPCD in counties with older housing stocks. Approximately 65 percent of the variation across counties in projected savings from toilets is explained by differences in housing stock age. This same relationship does not hold for clothes washers, as seen in Figure 8. Housing stock age is not a significant driver of projected water savings in the case of clothes washers. Clothes washers have much shorter average lifespans than toilets and they are mobile. Both factors help to decouple the age of the house from the age of its clothes washer.

Housing stock age is positively correlated with total savings, but the effect is not very large. This is shown in Figure 9, where R-GPCD savings in 2040 is plotted against the percent of the housing stock in 2014 constructed before 1990. The difference in the expected reduction in R-GPCD by 2040 between a county with 60 percent of its 2014 housing stock constructed before 1990 and one with 90 percent is only 0.67 GPCD.

[25] See Table 1.

[26] Data on the distribution of housing stock age is from the 2014 American Community Survey Five-Year Estimates.

Figure 7. Effect of Housing Stock Age on Toilet Water Savings from Efficiency Standards

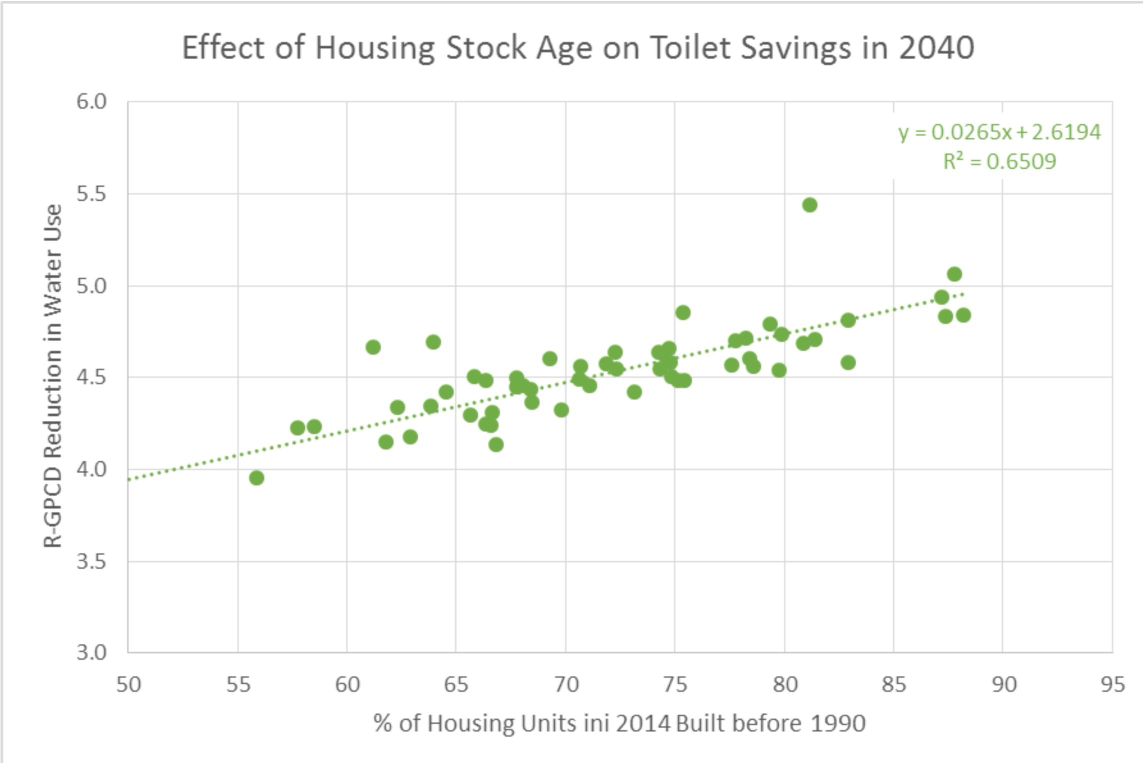


Figure 8. Effect of Housing Stock Age on Clothes Washer Water Savings from Efficiency Codes

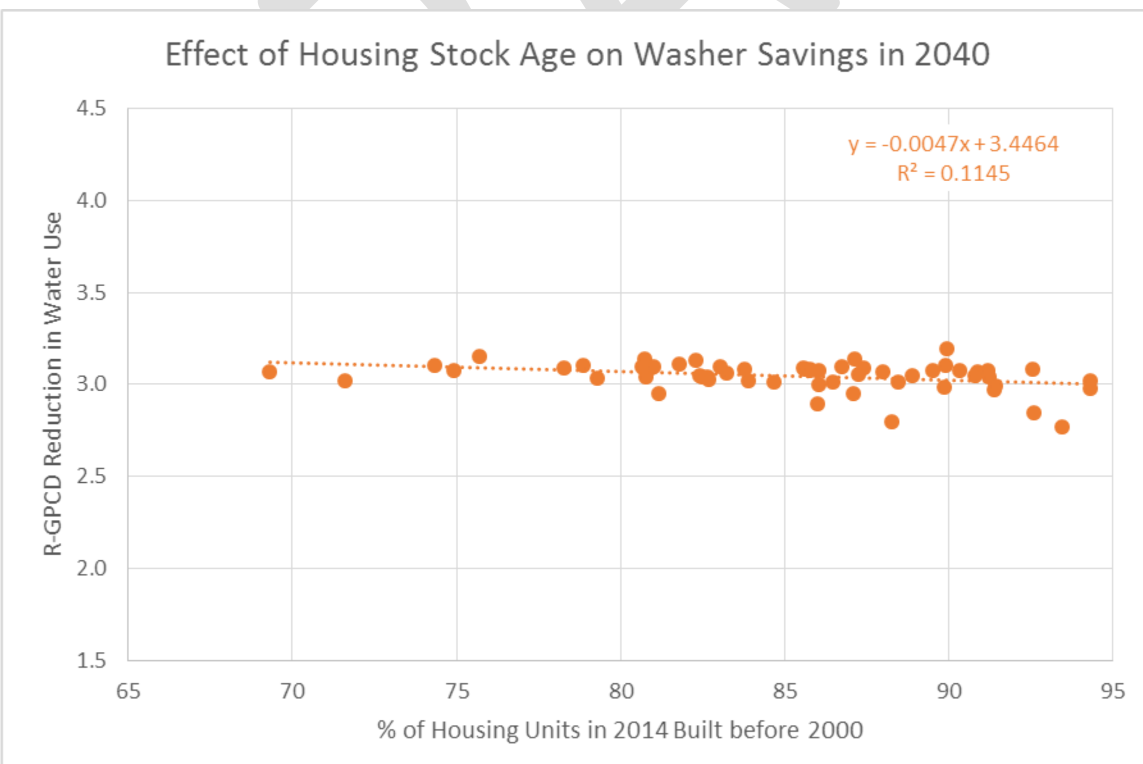
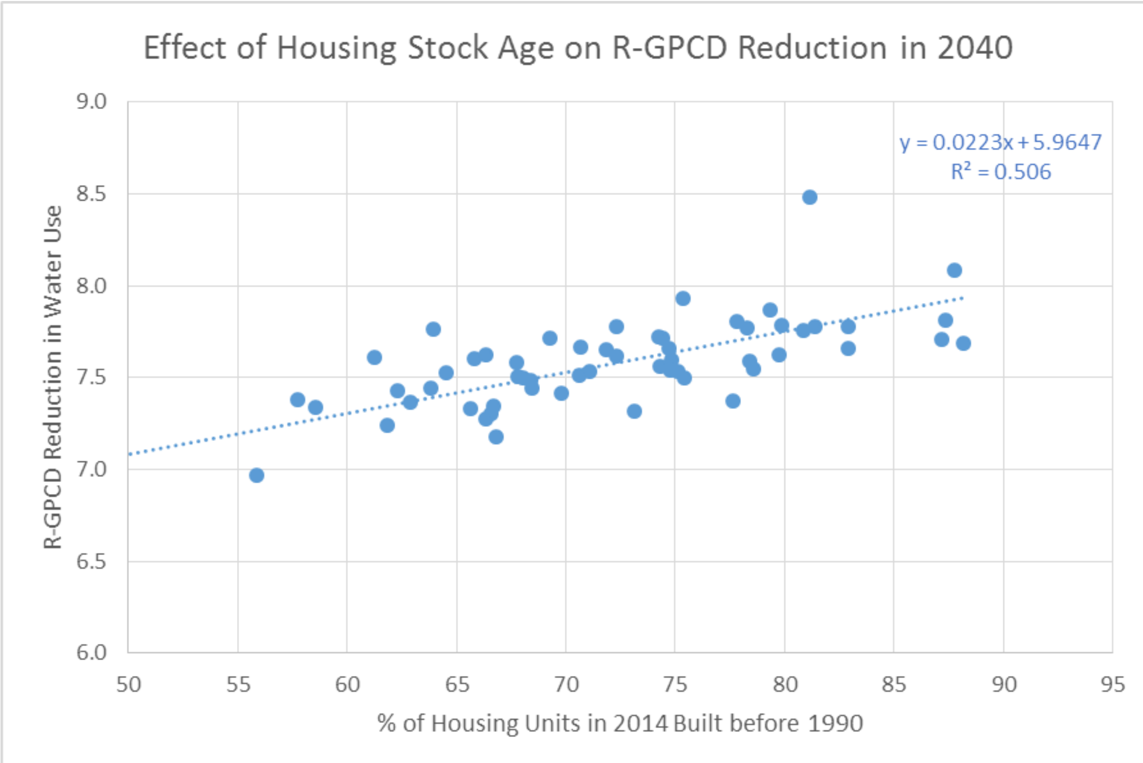


Figure 9. Effect of Housing Stock Age on R-GPCD Reduction from Efficiency Codes



5.5.2 R-GPCD Reduction by Hydrologic Region and County

Table 13 groups counties by primary hydrologic region and shows the average R-GPCD reduction and variability for each grouping.[27] The differences across hydrologic regions are small and likely well within the model's error.

Table 14 shows the average R-GPCD reduction in 2040 for each county within a hydrologic region. The largest county differences occur in the Sacramento River and South Lahontan hydrologic regions. But even in these two cases, the county-level differences are not large. It does not appear that differences in expected savings from plumbing codes and appliance standards would provide a strong justification for regionally differentiating urban water use reduction goals and targets.

[27] Some counties are in more than one hydrologic region. This study defines the county's primary hydrologic region as the one in which the majority of population is located.

Table 13. Projected 2040 R-GPCD Reduction by Hydrologic Region

Hydrologic Region	Number of Counties	Average R-GPCD Reduction	Standard Deviation	Minimum	Maximum
Central Coast	5	7.6	0.2	7.4	7.8
Colorado River	1	7.3	0.0	7.3	7.3
North Coast	6	7.6	0.1	7.5	7.8
North Lahontan	2	7.7	0.1	7.6	7.8
Sacramento River	16	7.5	0.3	6.7	7.9
San Francisco Bay	8	7.8	0.2	7.6	8.1
San Joaquin River	8	7.4	0.1	7.2	7.6
South Coast	6	7.4	0.2	7.0	7.7
South Lahontan	2	7.9	0.6	7.3	8.5
Tulare Lake	4	7.5	0.1	7.4	7.6
Statewide	**58**	**7.6**	**0.3**	**6.7**	**8.5**

Table 14. Projected 2040 R-GPCD Reduction by County

HR/County	Average R-GPCD Reduction in 2040	Standard Deviation	Minimum	Maximum
Central Coast	**7.6**	**0.2**	**7.4**	**7.8**
Monterey	7.8			
San Benito	7.4			
San Luis Obispo	7.4			
Santa Barbara	7.8			
Santa Cruz	7.7			
Colorado River	**7.3**	**0.0**	**7.3**	**7.3**
Imperial	7.3			
North Coast	**7.6**	**0.1**	**7.5**	**7.8**
Del Norte	7.5			
Humboldt	7.5			
Mendocino	7.8			
Siskiyou	7.8			
Sonoma	7.5			
Trinity	7.7			
North Lahontan	**7.7**	**0.1**	**7.6**	**7.8**
Alpine	7.6			
Lassen	7.8			
Sacramento River	**7.5**	**0.3**	**6.7**	**7.9**
Butte	7.7			
Colusa	7.7			

HR/County	Average R-GPCD Reduction in 2040	Standard Deviation	Minimum	Maximum
El Dorado	7.2			
Glenn	7.9			
Lake	7.6			
Modoc	7.8			
Nevada	7.4			
Placer	6.7			
Plumas	7.6			
Sacramento	7.5			
Shasta	7.7			
Sierra	7.6			
Sutter	7.6			
Tehama	7.5			
Yolo	7.3			
Yuba	7.8			
San Francisco Bay	**7.8**	**0.2**	**7.6**	**8.1**
Alameda	7.8			
Contra Costa	7.6			
Marin	7.8			
Napa	7.7			
San Francisco	7.7			
San Mateo	8.1			
Santa Clara	7.9			
Solano	7.7			
San Joaquin River	**7.4**	**0.1**	**7.2**	**7.6**
Amador	7.3			
Calaveras	7.2			
Madera	7.4			
Mariposa	7.3			
Merced	7.4			
San Joaquin	7.3			
Stanislaus	7.6			
Tuolumne	7.5			
South Coast	**7.4**	**0.2**	**7.0**	**7.7**
Los Angeles	7.7			
Orange	7.6			
Riverside	7.0			
San Bernardino	7.5			
San Diego	7.5			
Ventura	7.4			

HR/County	Average R-GPCD Reduction in 2040	Standard Deviation	Minimum	Maximum
South Lahontan	**7.9**	**0.6**	**7.3**	**8.5**
Inyo	8.5			
Mono	7.3			
Tulare Lake	**7.5**	**0.1**	**7.4**	**7.6**
Fresno	7.5			
Kern	7.5			
Kings	7.4			
Tulare	7.6			
Statewide	**7.6**	**0.3**	**6.7**	**8.5**

6 Summary and Conclusions

This analysis indicates that plumbing codes and appliance standards will temper growth in M&I water use in California over the next several decades, just as they have done over the previous 25 years. Plumbing codes and appliance standards are projected to annually save between 465 and 538 TAF statewide by 2040. This translates to a reduction of between 9 and 10 gallons per person per day.

The results from this study can be used to inform projections of baseline indoor R-GPCD over time. These baselines, in turn, can be used in the development of indoor R-GPCD reduction targets. The county-level estimates will enable the baselines to reflect regional differences due to age of the housing stock, differences in projected population and housing growth, differences in household density, and other factors affecting residential indoor water use, though the modeling done for this study suggests the impact of such differences on projected GPCD savings are not large across large areas such as counties or hydrologic regions. They may be more significant across smaller geographic units such as utility service areas. The models developed for this study can easily be adapted to small geographic units of analysis.

The study results can also help policymakers understand the underlying rate of transformation of the existing inventory of non-efficient plumbing fixtures. Because the models developed for this study are dynamic, they provide insight into how fast or slow appliance efficiency can be expected to change over time under existing codes and standards. This can be useful for establishing timeframes for meeting water use targets. One of the goals of setting targets is to accelerate transformation of inefficient fixtures to efficient fixtures. However, in order to ensure realistic time-frames for doing this, it is necessary to have an understanding of the underlying "natural" rate of transformation. The models developed for this study provide one way in which this understanding can be developed.

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Attachment 1. Plumbing Fixture Ownership and Property Resale Rates by County

		Avg Toilets Per Housing Unit		In Unit Washer Ownership Rate		Property Resale Rate	
County	SMSA Association	SFR	MFR	SFR	MFR	SFR	MFR
Alameda	'5775'	2.238	1.396	0.912	0.354	0.039	0.058
Alpine	'6920'	2.164	1.380	0.925	0.420	0.033	0.051
Amador	6920'	2.240	1.457	0.911	0.388	0.034	0.026
Butte	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Calaveras	6920'	2.240	1.457	0.911	0.388	0.034	0.026
Colusa	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Contra Costa	'7360'	2.290	1.330	0.918	0.290	0.039	0.058
Del Norte	6920'	2.240	1.457	0.911	0.388	0.038	0.032
El Dorado	6920'	2.240	1.457	0.911	0.388	0.037	0.037
Fresno	'6920'	2.164	1.380	0.925	0.420	0.040	0.038
Glenn	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Humboldt	6920'	2.240	1.457	0.911	0.388	0.038	0.032
Imperial	'6780'	2.240	1.457	0.911	0.388	0.022	0.012
Inyo	'6780'	2.240	1.457	0.911	0.388	0.111	0.123
Kern	'6920'	2.164	1.380	0.925	0.420	0.040	0.038
Kings	'6920'	2.164	1.380	0.925	0.420	0.040	0.038
Lake	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Lassen	'6920'	2.164	1.380	0.925	0.420	0.033	0.051
Los Angeles	'4480'	2.103	1.372	0.850	0.260	0.042	0.056
Madera	'6920'	2.164	1.380	0.925	0.420	0.034	0.026
Marin	'7360'	2.290	1.330	0.918	0.290	0.039	0.058
Mariposa	6920'	2.240	1.457	0.911	0.388	0.034	0.026
Mendocino	'6920'	2.164	1.380	0.925	0.420	0.038	0.032
Merced	'6920'	2.164	1.380	0.925	0.420	0.034	0.026
Modoc	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Mono	6920'	2.240	1.457	0.911	0.388	0.111	0.123

		Avg Toilets Per Housing Unit		In Unit Washer Ownership Rate		Property Resale Rate	
County	SMSA Association	SFR	MFR	SFR	MFR	SFR	MFR
Monterey	'7400'	2.361	1.333	0.946	0.356	0.033	0.012
Napa	'7360'	2.290	1.330	0.918	0.290	0.039	0.058
Nevada	6920'	2.240	1.457	0.911	0.388	0.037	0.037
Orange	'0360'	2.551	1.494	0.938	0.339	0.042	0.056
Placer	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Plumas	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Riverside	'6780'	2.240	1.457	0.911	0.388	0.042	0.056
Sacramento	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
San Benito	'7400'	2.361	1.333	0.946	0.356	0.033	0.012
San Bernardino	'6780'	2.240	1.457	0.911	0.388	0.042	0.056
San Diego	'7320'	2.386	1.440	0.915	0.362	0.042	0.056
San Francisco	'7360'	2.290	1.330	0.918	0.290	0.039	0.058
San Joaquin	6920'	2.240	1.457	0.911	0.388	0.034	0.026
San Luis Obispo	'7400'	2.361	1.333	0.946	0.356	0.033	0.012
San Mateo	'7360'	2.290	1.330	0.918	0.290	0.039	0.058
Santa Barbara	'7400'	2.361	1.333	0.946	0.356	0.033	0.012
Santa Clara	'7400'	2.361	1.333	0.946	0.356	0.039	0.058
Santa Cruz	'7400'	2.361	1.333	0.946	0.356	0.033	0.012
Shasta	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Sierra	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Siskiyou	'6920'	2.164	1.380	0.925	0.420	0.038	0.032
Solano	'6920'	2.164	1.380	0.925	0.420	0.039	0.058
Sonoma	'7360'	2.290	1.330	0.918	0.290	0.038	0.032
Stanislaus	'6920'	2.164	1.380	0.925	0.420	0.034	0.026
Sutter	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Tehama	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Trinity	'6920'	2.164	1.380	0.925	0.420	0.038	0.032

		Avg Toilets Per Housing Unit		In Unit Washer Ownership Rate		Property Resale Rate	
County	SMSA Association	SFR	MFR	SFR	MFR	SFR	MFR
Tulare	'6920'	2.164	1.380	0.925	0.420	0.040	0.038
Tuolumne	6920'	2.240	1.457	0.911	0.388	0.034	0.026
Ventura	'4480'	2.103	1.372	0.850	0.260	0.042	0.056
Yolo	'6920'	2.164	1.380	0.925	0.420	0.037	0.037
Yuba	'6920'	2.164	1.380	0.925	0.420	0.037	0.037

Attachment 2. Data for Calculation of Average Flush Rate for Non-Residential Toilets

Avg Flushes 1/	7.6	22.4	10.0	9.5	19.0	8.6	11.0	13.3	11.9	8.6	Avg. Flushes per Day 3/
GPD Savings 2/	16	47	21	20	40	18	23	28	25	18	
	CUWCC 1992 Toilet Inventory by County and Sector										
County	Hotels	Restaurant	Health Care	Offices	Retail/ Wholesale	Other	Industrial	Churches	Gov’t	Schools	
Alameda	17,096	4,949	21,068	47,700	42,809	11,174	13,804	2,748	3,894	7,322	12.3
Alpine	337	2	4	17	16	9	0	13	18	5	8.6
Amador	1,124	127	487	392	1,205	230	247	87	124	164	12.3
Butte	1,579	724	3,821	3,409	6,805	2,056	1,081	366	519	1,098	13.0
Calaveras	730	111	283	331	989	330	139	64	91	222	12.5
Colusa	337	69	147	123	466	230	96	32	45	143	12.3
Contra Costa	3,113	2,731	13,435	28,377	26,146	7,284	4,340	1,532	2,171	5,037	12.6
Del Norte	1,124	114	247	198	723	92	126	67	94	185	11.8
El Dorado	5,450	429	1,220	1,658	3,697	1,349	526	351	498	926	11.5
Fresno	8,752	2,296	11,635	14,351	21,667	4,335	4,075	1,171	1,660	5,557	12.6
Glenn	225	80	133	200	663	99	163	31	44	122	13.6
Humboldt	3,877	534	2,246	2,117	5,017	1,239	1,217	355	503	544	12.4
Imperial	1,348	327	936	1,137	3,910	443	258	171	242	1,138	13.5
Inyo	1,742	128	359	236	1,022	212	219	101	143	119	11.6
Kern	7,445	1,862	7,452	11,392	16,723	2,689	1,883	895	1,268	4,525	12.6
Kings	730	256	898	621	2,295	438	418	112	159	818	13.1
Lake	1,236	171	628	668	1,558	371	130	106	150	345	12.4
Lassen	899	93	314	250	770	154	144	62	89	184	12.0
Los Angeles	120,819	31,228	153,767	305,617	268,243	121,124	105,028	19,176	27,177	56,675	11.9
Madera	1,011	242	828	937	2,274	487	614	130	184	721	12.7
Marin	3,387	1,219	5,173	12,435	11,190	3,489	1,406	705	999	1,091	12.5
Mariposa	1,124	40	62	151	518	170	44	58	82	84	11.1
Mendocino	4,720	358	1,284	1,219	3,689	736	840	312	442	572	11.9
Merced	1,405	450	1,942	1,656	4,506	823	1,033	232	329	1,429	13.0
Modoc	281	37	22	62	313	34	36	19	27	60	12.9
Mono	2,528	143	75	244	513	184	22	112	158	61	10.2
Monterey	11,548	1,478	4,597	6,891	12,283	2,347	1,366	905	1,283	2,139	12.2

Avg Flushes 1/	7.6	22.4	10.0	9.5	19.0	8.6	11.0	13.3	11.9	8.6	
GPD Savings 2/	16	47	21	20	40	18	23	28	25	18	
	CUWCC 1992 Toilet Inventory by County and Sector										
County	Hotels	Restaurant	Health Care	Offices	Retail/ Wholesale	Other	Industrial	Churches	Gov't	Schools	Avg. Flushes per Day 3/
Napa	4,443	521	2,372	2,250	3,964	1,426	1,137	331	469	642	11.8
Nevada	1,967	337	1,479	1,950	3,219	1,123	650	223	317	602	12.3
Orange	57,938	10,701	52,997	111,864	84,645	21,463	33,422	6,291	8,916	12,578	11.8
Placer	2,247	970	3,627	4,207	6,861	2,290	1,331	417	590	1,186	12.8
Plumas	1,180	90	276	308	803	136	171	74	104	132	11.7
Riverside	17,413	3,347	12,244	16,729	28,959	7,343	4,254	1,690	2,395	7,839	12.4
Sacramento	10,889	4,355	15,728	36,929	34,414	9,460	4,730	2,061	2,920	7,007	12.5
San Benito	393	111	274	310	997	202	253	52	73	293	13.1
San Bernardino	17,580	4,628	17,331	23,851	41,516	9,425	9,934	2,282	3,234	11,400	12.6
San Diego	64,398	9,971	39,462	85,781	81,261	20,212	18,503	5,350	7,583	15,263	11.9
San Francisco	43,553	5,042	12,407	62,808	32,023	9,741	6,514	2,786	3,948	2,906	11.2
San Joaquin	4,600	1,467	7,839	7,942	14,277	3,187	3,657	769	1,090	3,346	12.7
San Luis Obispo	7,620	1,072	3,868	4,580	8,224	2,088	1,182	629	892	959	12.2
San Mateo	16,112	2,640	10,319	28,874	24,120	6,508	6,010	1,619	2,294	3,454	12.0
Santa Barbara	10,545	1,621	5,253	12,337	14,135	3,413	3,066	954	1,353	2,088	12.2
Santa Clara	26,682	5,973	23,249	72,675	49,194	13,010	27,612	3,755	5,322	8,726	11.9
Santa Cruz	4,141	1,019	4,165	6,084	8,447	2,761	1,967	569	807	1,317	12.4
Shasta	3,184	645	3,261	3,264	6,153	1,403	1,024	359	509	1,086	12.6
Sierra	169	7	17	19	59	0	45	9	12	26	10.7
Siskiyou	2,304	211	575	454	1,710	409	342	147	209	329	11.9
Solano	2,609	1,161	4,007	5,345	10,100	2,340	1,403	499	707	2,450	13.1
Sonoma	6,774	1,621	8,347	10,758	14,904	4,599	3,602	957	1,357	2,222	12.4
Stanislaus	3,537	1,187	6,007	5,616	12,247	2,610	3,268	615	872	2,666	12.9
Sutter	454	232	845	999	2,334	460	315	104	148	506	13.4
Tehama	1,236	163	478	510	1,491	285	356	102	144	347	12.4
Trinity	1,011	55	62	112	418	98	113	51	73	79	11.0
Tulare	3,427	881	3,996	3,852	8,882	1,743	1,852	448	635	2,159	12.9
Tuolumne	1,629	245	563	841	1,954	601	286	137	194	302	12.4
Ventura	6,751	2,243	11,071	20,307	20,622	5,732	5,513	1,287	1,825	4,357	12.3
Yolo	2,720	559	1,475	2,886	4,393	1,050	1,087	252	357	887	12.5

Avg Flushes 1/	7.6	22.4	10.0	9.5	19.0	8.6	11.0	13.3	11.9	8.6	
GPD Savings 2/	16	47	21	20	40	18	23	28	25	18	
	CUWCC 1992 Toilet Inventory by County and Sector										
County	Hotels	Restaurant	Health Care	Offices	Retail/ Wholesale	Other	Industrial	Churches	Gov’t	Schools	Avg. Flushes per Day 3/
Yuba	778	167	400	367	1,322	295	293	74	105	463	12.7

1/ Average flushes per day equal to GPD Savings divided by (3.9-1.8)
2/ GPD savings from CUWCC CII ULFT Savings Study (2001)
3/ Average flushes per day is a toilet population weighted average of the average daily flushes for toilets in each of the ten sectors.

Attachment 3. Plumbing Code and Appliance Standard Effects by County

Single-Family Effects

	Single-Family Population					SFR-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Statewide	29,298,916	30,611,455	31,908,231	33,159,820	34,286,582	2.9	4.9	6.1	7.0	7.6
County Variation										
Mean						2.9	4.9	6.1	7.0	7.6
St.Dev.						0.2	0.3	0.3	0.3	0.3
Min						2.7	4.4	5.5	6.2	6.7
Max						4.0	6.2	7.4	8.1	8.6
County										
Alameda	1,126,018	1,179,849	1,227,795	1,274,340	1,323,277	3.0	5.0	6.3	7.2	7.8
Alpine	714	733	732	717	692	2.9	5.1	6.5	7.4	8.1
Amador	32,901	34,326	35,281	35,917	36,267	2.7	4.6	5.9	6.7	7.3
Butte	192,296	200,728	207,615	214,147	217,149	3.1	5.1	6.3	7.2	7.7
Calaveras	46,827	49,195	50,994	52,528	53,455	2.9	4.7	5.9	6.7	7.2
Colusa	20,830	22,144	23,369	24,497	25,466	3.3	5.2	6.5	7.3	7.8
Contra Costa	938,142	984,285	1,030,233	1,078,860	1,126,508	2.9	4.8	6.1	7.0	7.6
Del Norte	22,398	22,840	23,204	23,309	23,302	2.9	4.9	6.1	7.0	7.6
El Dorado	168,894	174,297	178,276	181,917	184,101	2.8	4.6	5.8	6.6	7.2
Fresno	804,160	861,257	915,149	966,905	1,015,032	3.0	4.9	6.1	6.9	7.5
Glenn	25,803	26,899	27,898	28,824	29,626	3.1	5.1	6.5	7.4	8.0
Humboldt	113,508	114,847	115,040	113,995	112,794	3.0	4.9	6.2	7.0	7.6
Imperial	163,368	180,129	194,494	208,093	220,413	3.3	5.1	6.2	6.9	7.4
Inyo	17,234	17,565	17,735	17,728	17,656	4.0	6.2	7.4	8.1	8.6
Kern	801,544	881,448	962,482	1,045,759	1,130,239	3.2	5.0	6.2	7.0	7.5
Kings	123,204	132,567	141,619	150,786	160,476	2.9	4.8	6.1	6.9	7.4
Lake	64,511	68,834	72,596	76,118	78,945	2.9	5.0	6.3	7.1	7.7

	Single-Family Population					SFR-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Lassen	25,076	25,803	26,282	26,739	26,984	3.1	5.0	6.3	7.2	7.8
Los Angeles	6,589,721	6,756,158	6,899,762	7,024,690	7,130,402	2.9	4.9	6.2	7.1	7.7
Madera	144,317	157,706	170,787	184,684	198,580	3.0	4.9	6.1	6.9	7.4
Marin	193,748	194,327	195,710	198,138	200,837	2.9	4.8	6.2	7.2	7.8
Mariposa	17,453	18,541	18,994	19,286	19,225	2.7	4.8	6.0	6.8	7.3
Mendocino	77,271	78,782	79,926	80,658	81,205	2.9	4.9	6.2	7.2	7.8
Merced	238,658	258,552	279,514	300,846	321,973	2.8	4.8	6.0	6.9	7.4
Modoc	8,967	9,121	9,116	9,091	9,052	2.7	4.8	6.2	7.1	7.8
Mono	7,422	7,717	7,960	8,192	8,267	3.2	5.3	6.5	7.2	7.6
Monterey	321,641	333,358	343,449	352,382	360,322	3.0	5.0	6.4	7.3	7.9
Napa	115,317	118,949	122,564	125,581	128,030	2.9	4.9	6.2	7.1	7.7
Nevada	92,846	96,138	98,593	100,503	102,018	2.9	4.8	6.1	6.9	7.5
Orange	2,201,715	2,243,704	2,280,973	2,313,159	2,339,603	2.9	4.9	6.2	7.1	7.7
Placer	341,211	362,593	385,367	411,568	438,886	2.7	4.4	5.5	6.2	6.7
Plumas	18,120	18,199	18,082	17,794	17,315	2.7	4.6	6.0	6.9	7.6
Riverside	2,109,275	2,266,348	2,437,522	2,599,012	2,736,443	2.7	4.5	5.7	6.4	6.9
Sacramento	1,202,596	1,268,648	1,338,432	1,410,540	1,479,252	2.9	4.8	6.1	6.9	7.5
San Benito	54,273	58,488	62,872	67,120	71,001	2.9	4.8	6.1	6.9	7.5
San Bernardino	1,827,567	1,941,898	2,064,096	2,181,876	2,284,620	2.8	4.8	6.1	6.9	7.5
San Diego	2,258,546	2,329,831	2,400,878	2,465,527	2,525,919	2.9	4.8	6.1	7.0	7.6
San Francisco	374,526	391,596	406,324	418,131	431,003	3.0	5.0	6.3	7.2	7.8
San Joaquin	633,981	680,305	738,773	799,242	857,825	2.7	4.6	5.8	6.7	7.2
San Luis Obispo	227,242	235,000	241,194	247,711	247,890	2.8	4.7	6.0	6.9	7.5
San Mateo	562,094	579,376	595,170	612,886	632,398	3.2	5.2	6.6	7.5	8.2
Santa Barbara	322,438	334,619	346,496	359,083	363,717	3.0	5.0	6.4	7.4	8.0
Santa Clara	1,390,365	1,453,031	1,517,181	1,581,943	1,644,285	3.1	5.2	6.6	7.5	8.1
Santa Cruz	219,061	225,737	230,697	235,579	235,490	3.0	5.0	6.3	7.2	7.8
Shasta	158,855	165,717	171,204	175,944	179,667	3.0	5.0	6.3	7.1	7.7

	Single-Family Population					SFR-GPCD Reduction Relative to 2015				
	2020	2025	2030	2035	2040	2020	2025	2030	2035	2040
Sierra	3,052	2,972	2,890	2,807	2,722	2.7	4.6	6.0	6.9	7.6
Siskiyou	40,791	41,299	41,494	41,439	40,970	3.0	5.0	6.3	7.2	7.9
Solano	365,917	384,174	403,302	423,428	440,789	3.0	4.9	6.2	7.0	7.6
Sonoma	429,619	447,948	464,720	480,193	494,095	2.9	4.8	6.1	7.0	7.6
Stanislaus	492,046	524,197	555,522	584,568	613,043	3.0	4.9	6.2	7.0	7.6
Sutter	86,356	92,326	98,617	105,613	112,761	3.0	4.9	6.2	7.0	7.6
Tehama	59,863	61,625	63,206	64,484	65,100	2.8	4.7	6.0	6.9	7.5
Trinity	13,010	13,259	13,315	13,229	13,031	3.1	5.1	6.3	7.2	7.8
Tulare	430,263	463,443	499,489	532,216	561,800	3.1	5.0	6.3	7.1	7.6
Tuolumne	48,051	49,139	50,151	51,045	51,269	2.7	4.7	6.1	7.0	7.6
Ventura	710,039	731,519	751,316	769,281	782,499	2.7	4.6	5.9	6.8	7.4
Yolo	156,228	164,729	173,268	184,435	190,202	2.9	4.7	6.0	6.8	7.4
Yuba	67,024	72,639	78,511	84,738	90,692	3.0	5.0	6.4	7.2	7.8

Multi-Family Effects

	Multi-Family Population					MFR-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Statewide	10,451,798	10,848,737	11,228,510	11,587,861	11,913,514	2.7	4.8	6.1	6.9	7.5
County Variation										
Mean						2.7	4.8	6.1	6.9	7.5
St.Dev.						0.2	0.3	0.3	0.4	0.4
Min						2.3	4.0	5.1	5.8	6.2
Max						3.2	5.5	6.7	7.4	8.0
County										
Alameda	513,823	538,387	560,265	581,505	603,836	2.8	5.0	6.3	7.2	7.7
Alpine	552	566	566	555	534	2.4	4.4	5.6	6.4	7.0
Amador	1,829	1,908	1,961	1,996	2,016	2.4	4.4	5.7	6.5	7.1
Butte	39,674	41,414	42,834	44,182	44,801	2.9	4.9	6.2	7.0	7.6
Calaveras	1,611	1,693	1,754	1,807	1,839	2.9	4.9	6.2	7.1	7.7
Colusa	3,199	3,401	3,589	3,762	3,911	2.7	4.5	5.6	6.4	6.8
Contra Costa	217,247	227,932	238,572	249,833	260,867	2.7	4.8	6.1	7.0	7.5
Del Norte	3,141	3,203	3,254	3,269	3,267	2.5	4.3	5.5	6.3	6.9
El Dorado	20,314	20,964	21,442	21,880	22,143	2.7	4.5	5.8	6.6	7.2
Fresno	232,550	249,061	264,645	279,612	293,530	2.8	4.8	6.1	7.0	7.6
Glenn	4,314	4,497	4,664	4,819	4,953	2.7	4.7	6.1	7.0	7.6
Humboldt	20,736	20,980	21,016	20,825	20,606	2.6	4.4	5.6	6.4	7.0
Imperial	36,530	40,278	43,490	46,531	49,286	3.1	4.8	5.9	6.6	7.1
Inyo	1,988	2,026	2,046	2,045	2,037	3.2	5.5	6.7	7.3	7.8
Kern	147,591	162,304	177,226	192,560	208,115	3.0	5.0	6.2	7.0	7.5
Kings	22,076	23,753	25,375	27,017	28,754	2.7	4.8	6.1	6.9	7.5
Lake	5,121	5,464	5,763	6,042	6,267	2.4	4.2	5.4	6.1	6.6
Lassen	1,586	1,631	1,662	1,691	1,706	2.8	5.1	6.5	7.4	8.0

	Multi-Family Population					MFR-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Los Angeles	3,663,348	3,755,873	3,835,706	3,905,156	3,963,923	2.7	4.8	6.2	7.1	7.7
Madera	19,585	21,402	23,177	25,063	26,949	2.8	4.6	5.8	6.6	7.1
Marin	57,190	57,361	57,769	58,486	59,283	2.5	4.7	6.1	7.0	7.7
Mariposa	1,083	1,151	1,179	1,197	1,193	2.3	4.0	5.2	5.9	6.4
Mendocino	11,290	11,510	11,678	11,785	11,865	2.6	4.6	5.9	6.8	7.5
Merced	45,059	48,815	52,773	56,801	60,789	2.7	4.6	6.0	6.8	7.4
Modoc	367	374	374	373	371	2.4	4.5	6.0	7.0	7.7
Mono	7,460	7,757	8,001	8,234	8,309	2.7	4.8	5.9	6.6	7.0
Monterey	102,956	106,706	109,936	112,795	115,337	2.6	4.4	5.7	6.7	7.3
Napa	26,560	27,396	28,229	28,924	29,488	2.7	4.7	6.0	6.9	7.5
Nevada	7,783	8,058	8,264	8,424	8,551	2.5	4.3	5.5	6.3	6.9
Orange	995,779	1,014,769	1,031,625	1,046,182	1,058,142	2.6	4.7	6.0	6.8	7.4
Placer	50,953	54,146	57,546	61,459	65,538	2.4	4.0	5.1	5.8	6.2
Plumas	893	897	891	877	853	2.5	4.5	6.0	7.0	7.7
Riverside	329,972	354,544	381,322	406,586	428,085	2.7	4.7	6.0	6.7	7.2
Sacramento	327,106	345,072	364,054	383,667	402,357	2.8	4.8	6.1	7.0	7.6
San Benito	8,819	9,504	10,217	10,907	11,538	2.6	4.3	5.5	6.3	6.9
San Bernardino	357,040	379,376	403,249	426,259	446,331	2.7	4.8	6.2	7.0	7.6
San Diego	1,014,668	1,046,693	1,078,611	1,107,655	1,134,787	2.7	4.7	6.0	6.8	7.4
San Francisco	491,890	514,310	533,653	549,159	566,065	2.7	4.9	6.2	7.0	7.6
San Joaquin	117,393	125,970	136,797	147,993	158,841	2.7	4.8	6.2	7.2	7.8
San Luis Obispo	39,489	40,837	41,913	43,045	43,076	2.5	4.3	5.5	6.5	7.1
San Mateo	205,782	212,110	217,892	224,377	231,520	2.9	5.0	6.4	7.3	7.9
Santa Barbara	115,302	119,657	123,904	128,406	130,063	2.6	4.4	5.7	6.6	7.2
Santa Clara	548,814	573,549	598,872	624,434	649,043	2.7	4.6	5.9	6.7	7.2
Santa Cruz	52,004	53,589	54,766	55,925	55,904	2.4	4.2	5.4	6.3	6.9
Shasta	26,077	27,204	28,104	28,882	29,494	2.7	4.6	5.9	6.8	7.3
Sierra	88	86	84	81	79	2.5	4.6	6.0	7.0	7.7

	Multi-Family Population					MFR-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Siskiyou	4,977	5,039	5,063	5,056	4,999	2.4	4.2	5.5	6.3	6.9
Solano	75,845	79,630	83,594	87,766	91,365	2.9	5.1	6.5	7.3	7.9
Sonoma	83,498	87,061	90,321	93,328	96,030	2.5	4.3	5.5	6.4	7.0
Stanislaus	74,818	79,707	84,470	88,887	93,217	2.9	4.8	6.1	7.0	7.6
Sutter	17,577	18,792	20,072	21,497	22,951	2.9	4.9	6.2	7.1	7.7
Tehama	6,577	6,770	6,944	7,084	7,152	2.5	4.6	5.9	6.9	7.5
Trinity	855	872	875	870	857	2.4	4.0	5.1	5.9	6.4
Tulare	62,905	67,756	73,026	77,810	82,136	2.8	4.8	6.0	6.9	7.4
Tuolumne	3,699	3,783	3,860	3,929	3,946	2.3	4.1	5.4	6.3	6.9
Ventura	155,612	160,320	164,658	168,595	171,492	2.5	4.5	5.8	6.7	7.3
Yolo	53,589	56,506	59,434	63,265	65,244	2.6	4.5	5.8	6.7	7.3
Yuba	13,217	14,324	15,483	16,710	17,885	2.8	5.0	6.3	7.2	7.8

Total Effects, including Common Area and Coin-Op Clothes Washers and Non-Residential Toilets and Urinals

	Total Population					GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Statewide	40,616,702	42,373,655	44,099,585	45,747,645	47,233,240	3.6	6.1	7.8	8.9	9.7
County Variation										
Mean						3.6	6.1	7.8	8.9	9.7
St.Dev.						0.4	0.6	0.8	0.8	0.9
Min						2.8	4.7	6.0	6.8	7.4
Max						5.4	8.8	10.7	11.7	12.4
County										
Alameda	1,682,642	1,763,556	1,835,884	1,905,482	1,978,656	3.7	6.4	8.1	9.2	10.0
Alpine	1,290	1,323	1,322	1,296	1,249	3.9	7.1	9.1	10.5	11.4
Amador	39,114	40,834	41,991	42,748	43,165	3.0	5.3	6.9	7.9	8.6
Butte	237,027	247,492	256,092	264,150	267,852	3.7	6.2	7.9	9.0	9.7
Calaveras	48,940	51,421	53,308	54,912	55,881	3.5	5.8	7.3	8.3	9.0
Colusa	24,270	25,806	27,243	28,558	29,688	3.9	6.3	7.9	8.9	9.6
Contra Costa	1,166,281	1,223,830	1,281,265	1,341,741	1,400,999	3.6	6.1	7.7	8.9	9.6
Del Norte	29,204	29,798	30,281	30,418	30,408	3.1	5.2	6.7	7.7	8.4
El Dorado	190,850	196,978	201,508	205,624	208,092	3.4	5.8	7.3	8.4	9.1
Fresno	1,055,541	1,130,696	1,201,749	1,269,714	1,332,913	3.6	6.0	7.5	8.6	9.3
Glenn	30,440	31,736	32,920	34,013	34,959	3.6	6.0	7.7	8.8	9.6
Humboldt	139,107	140,784	141,061	139,780	138,307	3.6	6.1	7.7	8.9	9.7
Imperial	212,134	233,964	252,665	270,331	286,336	3.8	5.8	7.1	8.0	8.5
Inyo	19,652	20,037	20,243	20,235	20,153	5.4	8.8	10.7	11.7	12.4
Kern	989,868	1,088,782	1,189,065	1,291,947	1,396,314	3.7	6.0	7.4	8.4	9.0
Kings	167,479	180,333	192,731	205,206	218,394	3.0	5.0	6.4	7.3	7.9
Lake	70,758	75,515	79,668	83,532	86,635	3.5	6.0	7.6	8.7	9.4
Lassen	36,247	37,347	38,057	38,719	39,073	2.8	4.7	6.0	6.8	7.4

	Total Population					GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Los Angeles	10,429,648	10,695,097	10,925,298	11,123,113	11,290,501	3.6	6.3	8.2	9.4	10.2
Madera	173,251	189,380	205,132	221,824	238,514	3.4	5.5	6.9	7.8	8.5
Marin	259,756	260,618	262,582	265,840	269,462	3.6	6.4	8.3	9.6	10.5
Mariposa	19,258	20,463	20,966	21,288	21,221	3.4	5.9	7.5	8.5	9.3
Mendocino	90,551	92,340	93,707	94,565	95,207	3.7	6.3	8.1	9.4	10.3
Merced	288,944	313,074	338,513	364,348	389,934	3.3	5.6	7.1	8.2	8.8
Modoc	9,669	9,839	9,839	9,812	9,770	3.2	5.6	7.3	8.4	9.3
Mono	15,103	15,705	16,199	16,671	16,823	4.7	8.2	10.1	11.2	11.9
Monterey	446,198	462,607	476,771	489,171	500,194	3.4	5.8	7.5	8.7	9.5
Napa	146,872	151,573	156,298	160,146	163,269	3.6	6.2	8.0	9.2	10.0
Nevada	101,780	105,407	108,129	110,224	111,885	3.6	6.2	7.9	9.0	9.8
Orange	3,244,594	3,307,127	3,363,054	3,410,509	3,449,498	3.6	6.3	8.0	9.2	10.0
Placer	396,267	421,174	447,753	478,196	509,936	3.3	5.5	6.9	7.9	8.6
Plumas	19,266	19,354	19,235	18,929	18,419	3.4	5.9	7.7	9.0	9.9
Riverside	2,477,634	2,662,495	2,864,062	3,053,812	3,215,291	3.2	5.4	6.9	7.8	8.4
Sacramento	1,554,422	1,640,092	1,730,742	1,823,985	1,912,838	3.5	6.0	7.6	8.7	9.5
San Benito	63,406	68,337	73,470	78,434	82,969	3.4	5.7	7.2	8.2	8.9
San Bernardino	2,226,102	2,365,725	2,515,044	2,658,556	2,783,746	3.4	5.8	7.4	8.5	9.2
San Diego	3,378,184	3,485,623	3,592,840	3,689,585	3,779,961	3.5	6.1	7.7	8.9	9.6
San Francisco	891,823	932,744	968,199	996,332	1,027,004	4.0	7.2	9.2	10.5	11.4
San Joaquin	766,586	822,771	893,737	966,889	1,037,761	3.2	5.6	7.2	8.3	9.0
San Luis Obispo	283,706	293,496	301,324	309,465	309,689	3.3	5.6	7.2	8.4	9.1
San Mateo	776,984	801,037	823,140	847,641	874,626	3.9	6.8	8.6	9.9	10.7
Santa Barbara	455,839	473,184	490,107	507,912	514,466	3.5	6.0	7.7	8.9	9.7
Santa Clara	1,971,008	2,060,189	2,151,631	2,243,474	2,331,887	3.8	6.5	8.3	9.5	10.2
Santa Cruz	282,195	290,870	297,334	303,626	303,512	3.4	5.8	7.5	8.7	9.5
Shasta	187,598	195,735	202,265	207,865	212,264	3.7	6.2	7.9	9.1	9.8
Sierra	3,170	3,088	3,005	2,918	2,830	3.2	5.6	7.3	8.5	9.3

	Total Population					GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**	**2020**	**2025**	**2030**	**2035**	**2040**
Siskiyou	46,230	46,811	47,039	46,976	46,445	3.7	6.3	8.0	9.2	10.1
Solano	454,746	477,540	501,436	526,460	548,046	3.5	6.0	7.6	8.6	9.3
Sonoma	523,421	545,882	566,511	585,373	602,320	3.5	6.0	7.7	8.9	9.7
Stanislaus	573,542	611,129	647,830	681,703	714,910	3.6	5.9	7.5	8.6	9.3
Sutter	105,048	112,330	120,015	128,530	137,228	3.6	6.0	7.6	8.7	9.4
Tehama	67,285	69,275	71,067	72,504	73,196	3.3	5.7	7.3	8.4	9.1
Trinity	14,238	14,514	14,577	14,484	14,267	3.7	6.2	7.8	9.0	9.8
Tulare	498,267	536,766	578,635	616,547	650,819	3.6	6.0	7.5	8.5	9.2
Tuolumne	56,024	57,317	58,517	59,560	59,821	3.1	5.5	7.2	8.4	9.2
Ventura	876,346	902,978	927,585	949,765	966,084	3.4	6.0	7.7	8.9	9.7
Yolo	219,408	231,413	243,471	259,163	267,268	3.3	5.6	7.1	8.2	8.9
Yuba	81,489	88,324	95,473	103,044	110,285	3.5	5.9	7.5	8.6	9.2

Attachment 4. R-GPCD Reduction by County

	R-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**
Statewide	2.9	4.8	6.1	7.0	7.6
County Variation					
Mean	2.9	4.8	6.1	7.0	7.6
St.Dev.	0.2	0.2	0.2	0.2	0.3
Min	2.7	4.3	5.4	6.2	6.7
Max	4.0	6.1	7.3	8.0	8.5
County					
Alameda	3.0	5.0	6.3	7.2	7.8
Alpine	2.7	4.8	6.1	7.0	7.6
Amador	2.7	4.6	5.9	6.7	7.3
Butte	3.0	5.0	6.3	7.2	7.7
Calaveras	2.9	4.7	5.9	6.7	7.2
Colusa	3.2	5.1	6.4	7.2	7.7
Contra Costa	2.9	4.8	6.1	7.0	7.6
Del Norte	2.9	4.8	6.0	6.9	7.5
El Dorado	2.8	4.6	5.8	6.6	7.2
Fresno	2.9	4.9	6.1	7.0	7.5
Glenn	3.0	5.1	6.4	7.3	7.9
Humboldt	2.9	4.8	6.1	6.9	7.5
Imperial	3.3	5.0	6.1	6.9	7.3
Inyo	4.0	6.1	7.3	8.0	8.5
Kern	3.2	5.0	6.2	7.0	7.5
Kings	2.9	4.8	6.1	6.9	7.4
Lake	2.9	4.9	6.2	7.0	7.6
Lassen	3.1	5.0	6.3	7.2	7.8
Los Angeles	2.8	4.8	6.2	7.1	7.7
Madera	3.0	4.9	6.1	6.9	7.4
Marin	2.8	4.8	6.2	7.1	7.8
Mariposa	2.7	4.7	5.9	6.7	7.3
Mendocino	2.9	4.9	6.2	7.1	7.8
Merced	2.8	4.7	6.0	6.9	7.4
Modoc	2.7	4.8	6.2	7.1	7.8
Mono	2.9	5.0	6.2	6.9	7.3
Monterey	2.9	4.9	6.2	7.2	7.8
Napa	2.9	4.8	6.2	7.1	7.7
Nevada	2.8	4.8	6.0	6.9	7.4
Orange	2.8	4.8	6.1	7.0	7.6

	R-GPCD Reduction Relative to 2015				
	2020	**2025**	**2030**	**2035**	**2040**
Placer	2.7	4.3	5.4	6.2	6.7
Plumas	2.7	4.6	6.0	6.9	7.6
Riverside	2.7	4.5	5.7	6.5	7.0
Sacramento	2.9	4.8	6.1	7.0	7.5
San Benito	2.9	4.8	6.0	6.8	7.4
San Bernardino	2.8	4.8	6.1	7.0	7.5
San Diego	2.8	4.8	6.1	7.0	7.5
San Francisco	2.9	4.9	6.3	7.1	7.7
San Joaquin	2.7	4.6	5.9	6.8	7.3
San Luis Obispo	2.8	4.7	6.0	6.8	7.4
San Mateo	3.1	5.2	6.6	7.5	8.1
Santa Barbara	2.9	4.9	6.2	7.2	7.8
Santa Clara	3.0	5.0	6.4	7.3	7.9
Santa Cruz	2.9	4.8	6.1	7.0	7.7
Shasta	3.0	4.9	6.2	7.1	7.7
Sierra	2.7	4.6	6.0	6.9	7.6
Siskiyou	2.9	4.9	6.2	7.1	7.8
Solano	3.0	5.0	6.3	7.1	7.7
Sonoma	2.8	4.7	6.0	6.9	7.5
Stanislaus	3.0	4.9	6.2	7.0	7.6
Sutter	3.0	4.9	6.2	7.1	7.6
Tehama	2.8	4.7	6.0	6.9	7.5
Trinity	3.1	5.0	6.3	7.1	7.7
Tulare	3.0	5.0	6.3	7.1	7.6
Tuolumne	2.7	4.7	6.0	6.9	7.5
Ventura	2.7	4.6	5.9	6.8	7.4
Yolo	2.8	4.7	5.9	6.8	7.3
Yuba	3.0	5.0	6.4	7.2	7.8