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Methodology for the National Water Savings Model and Spreadsheet Tool–Commercial/Institutional

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METHODOLOGY FOR THE NATIONAL WATER SAVINGS MODEL AND SPREADSHEET TOOL–COMMERCIAL/INSTITUTIONAL

Camilla Dunham Whitehead, Peter Chan, Tim Long, Alison Williams, and Moya Melody

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METHODOLOGY FOR THE NATIONAL WATER SAVINGS MODEL AND SPREADSHEET TOOL–COMMERCIAL/INSTITUTIONAL

1 INTRODUCTION

Lawrence Berkeley National Laboratory (LBNL) has developed a mathematical model to quantify the water and monetary savings attributable to the United States Environmental Protection Agency's (EPA's) WaterSense labeling program for commercial and institutional products. The National Water Savings–Commercial/Institutional (NWS-CI) model is a spreadsheet tool with which the EPA can evaluate the success of its program for encouraging buyers in the commercial and institutional (CI) sectors to purchase more water-efficient products. WaterSense has begun by focusing on three water-using products commonly used in the CI sectors: flushometer valve toilets, urinals, and pre-rinse spray valves. EPA places its WaterSense label on products that have higher water efficiencies (use less water) than the federally required maximum. The NWS-CI model forecasts the amounts of water that would be consumed nationally by the three products both with and without the WaterSense program. In developing inputs to the model, numerous sources were consulted, which are described in a separate literature review (Whitehead et al., 2009).

To estimate the savings attributable to WaterSense for each of the three products, LBNL applies an accounting method to national product shipments and lifetimes to estimate the shipments of each product. The calculation of baseline water use relies on three values for each product: the number of units in use; the number of events per unit; and the water consumed per event, or unit water consumption (UWC). The number of units is derived from a shipments model that incorporates the year of interest, the unit age or vintage, and the building type. The events per unit depend on building occupancy, which is assumed to be a function of building type. The UWC is based on market share data and existing efficiency standards. This report describes the data LBNL collected and the calculations it used to develop estimates of the three values for all three products. To quantify the monetary value of the water savings attributable to the WaterSense CI program, LBNL also developed prices for water and wastewater services nationwide.

In developing the NWS-CI model, LBNL assumed that each of the three labeled products is used in an identical fashion as its unlabeled counterpart or the product it replaces. For example, a WaterSense pre-rinse spray valve is assumed to be operated for the same amount of time as the pre-rinse valve it replaces or as an unlabeled pre-rinse spray valve. LBNL also assumed that products are not used differently in different areas of the country, so that, for example, people were assumed to use toilets in the same manner in all areas of the

United States. It was assumed, however, that the products experience different frequencies of use in different types of CI enterprises. For example, office buildings are occupied for longer hours than schools; therefore, the toilets and urinals within office buildings experience greater use.

Section 2 summarizes the model and the inputs required for the calculations of water and monetary savings under WaterSense. Section 3 describes the types of and sources for the data used for each input. Section 4 reviews the way annual water consumption savings are calculated and describes the method used to develop commercial water and wastewater prices. Results will be presented after the model is finalized.

2 MODEL OVERVIEW

Calculating savings attributable to the WaterSense program involves three broad steps. In the first step, a base-case consumption is established for each end-use under consideration (e.g., flushing a toilet or urinal or rinsing dishes with a pre-rinse spray valve). Annual water use consumption for each product is based on the end-use consumption and the number of end-uses. In the second step, a forecast of market trends for product efficiencies is determined for both the base-case and the WaterSense policy case. The third step relies on both previous steps, combined with product sales and lifetimes, to determine national water savings. LBNL calculated the cumulative national water savings attributable to the WaterSense program for two forecast periods of 7 years and 30 years, representing the maximum lifetime of a WaterSense pre-rinse spray value and the maximum lifetime of a WaterSense flushometer valve toilet or urinal, respectively. The rest of this section presents the equations LBNL used to calculate water savings.

For the calculation of national water savings (NWS), the model is the sum of water savings for each year. The national annual water consumption (AWC) is the product of the AWC per unit and the number of units of each vintage. This method of calculation accounts for differences in unit water consumption from year to year. The equation for determining the AWC is presented in section 2.1.5. National AWC is described further in section 4. It should be noted that the NWS-CI does not estimate total water use in the commercial and institutional sectors. Insufficient data exist on the types and variety of water uses in the CI sectors to calculate that total. That total is not required for this analysis.

2.1 Equations

The inputs to the calculation of NWS are:

- shipments, product survival function (*STOCK*),
- frequency of use (*FREQUENCY*),
- annual water consumption per unit (*UWC*),
- national annual water consumption (*AWC*).

The inputs are described briefly below. Sources for and types of data for developing each input are described in Section 3.

2.1.1 Shipments

The NWS-CI model tracks the number of units of each product type shipped each year. LBNL forecasted shipments for each product using a retirement function, historic shipments data, and commercial floor space estimates.

The model considers market segments as distinct inputs to the shipments forecast. As represented by the following equation, the primary market segments are new installations and replacements.

$$Ship(y) = Rpl(y) + NI(y)$$

Where:

Ship(y) =	total shipments of a WaterSense product in year *y*,
Rpl (y) =	units retired and replaced in year *y*, and
NI (y) =	number of new units installed in year *y*.

Because the products currently subject to WaterSense labeling have been used by the CI sectors for decades, most shipments represent replacements. Most of those replacements occur when a unit fails. Depending on a product's age, a certain percentage of units will fail and need to be replaced. LBNL used a triangular retirement function to calculate the number of retiring units in a given year. Commercial floor space retirement estimates were used to approximate demolitions. To determine shipments to the replacement market, LBNL uses the following equation:

$$Rpl(y) = \left(\sum_{y-40}^{y} Ship(y) \times R(y)\right) - Demo$$

Where:

Rpl (y) = units retired and replaced in year *y*, in this model
Ship(y) = total shipments of a given WaterSense product in year *y*,
R(y) = retirement probability for year y, and
Demo = factor to account for commercial building demolition.

Demolitions were calculated using the following equation:

$$Demo = Floor_y \times Saturation_{y-10}$$

Where:

$Floor_y$ = retiring floor space in the current year, and
$Saturation_{y-10}$ = product saturation 10 years before the current year.

New construction shipments were calculated using the following equation:

$$NI(y) = NI(y-1) \times Growth$$

Where:

NI(y) = units shipped to new commercial buildings in year y,
NI(y-1) = units shipped to new commercial buildings in the year y-1, and
Growth = commercial floorspace growth rate between years y and y-1.

For years prior to 2011, the first year of the shipments model, new construction shipments are calculated as the difference between shipments and replacement units.

2.1.2 Product Stock

In order to determine national water usage, LBNL developed national stock models for the three water-using CI products. The product stock in a given year is the sum of the surviving products shipped in earlier years and the shipments in that year. LBNL assumed that products have an increasing probability of retiring as they age. The probability of retirement as a function of years since purchase is termed the retirement function.

Stock accounting provides an estimate of the age distribution of product stocks for all years, using as inputs product shipments, a survival function, and initial product stock. The age distribution of the product stock is a key input to the calculation of NWS, because the operating costs for any year depend on the age distribution of the stock. The WaterSense scenario produces increasing efficiency over time: older, less efficient units have higher water use rates. As units are added to the in-service stock, some older ones are retired and exit the stock.

LBNL calculated the total stock of each product by using the following equation:

$$Stock(y) = \sum_{i=y-1}^{i=y-40} \left(Ship(i) \times Surv(i) \right) + Ship(y)$$

Where:

Stock(y) = number of units in year y,
Surv(i) = the percentage of units surviving in previous years,
Ship(i) = shipments for previous years, and
Ship(y) = number of units purchased in year *y*.

The survival function is calculated based on the triangular retirement distribution mentioned earlier and has the form:

$$Surv(y) = 1 - \sum_{i=0}^{y} R(i)$$

Where:

R = the triangular retirement distribution.

The maximum probability of retirement occurs at the average lifetime. The probability is scaled so that the area under the curve equals 100 percent.

The sources for and types of data used to develop stocks of the three WaterSense CI products for the NWS-CI model are described in Section 3.2.

2.1.3 Frequency of Use (Urinals and Flushometer Valve Toilets)

Calculating the frequency with which a urinal or flushometer valve toilet is used in a given type of CI enterprise requires multiplying the number of occupants in a particular commercial enterprise or building type by the frequency of use for units installed in that enterprise or building type, and dividing by the number of units present. The sources for and types of data used to develop frequency of use for each product for the NWS-CI model are described in Section 3.3. The inputs used for determining per-unit usage for a particular building or enterprise type are:

A(b,e): Number of flushes per day per person, by building type (b) and occupant type (e),
B(b, e, w): Number of persons by building type (b), occupant type (e), and worksize type (w),
C(b, e, w): Number of units by building type (b), occupant type (e), and worksize type (w), and
M(b, w): Percentage of buildings by worksize type (w) for each building type (b).

To determine the number of flushes per day by building type, occupant type, and worksize type, the following equation was used:

$$D(b,e,w) = A(b,e)\ x\ B(b,e,w)$$

To determine the number of flushes per day by building type and worksize type, the following equation was used:

$$E(b,w) = \sum_{e} D(b,e,w)$$

To determine the number of units by building type and worksize type, the following equation was used:

$$F(b,w) = \sum_{e} C(b,e,w)$$

To determine the number of flushes per day per toilet by building type and worksize type, the following equation was used:

$$G(b,w) = \frac{E(b,w)}{F(b,w)}$$

To determine the percent of toilets by worksize type for each building type, the following equation was used:

$$X(b,w) = M(b,w)\ x\ F(b,w)$$

To determine the number of flushes per day per toilet for each building type, the following equation was used:

$$FREQUENCY(b) = \sum G(b,w)\ x\ X(b,w)$$

2.1.4 Frequency of Use (Pre-rinse Spray Valves)

Calculating the frequency with which a pre-rinse spray valve is used in a given type of CI enterprise requires multiplying the number of occupants in a particular commercial enterprise or building type by the frequency of use for units installed in that enterprise or building type, and dividing by the number of units present. The sources for and types of data used to develop frequency of use for each product for the NWS-CI model are described in Section 3.3. The inputs used for determining per-unit usage for a particular building or enterprise type are:

J(b, w): Number of PRVs per building by building type and worksize type, and
K(b,w): Usage per PRV by building type and worksize type.

To determine PRV usage by building type, the following equation was used:

$$FREQUENCY(b) = \sum J(b,w)\ x\ K(b,w)$$

2.1.5 Water Consumption per Unit

LBNL used the shipment-weighted water efficiencies presented in section 3.4 for the base case and the WaterSense case, along with the data on annual water consumption, to estimate the shipment-weighted average annual per-unit water consumption under the base case and WaterSense case. LBNL assumes that the efficiency mix in the product stock includes products that meet either the Federal standard or the WaterSense label requirements.

2.1.6 National Annual Water Consumption

The following equation shows that LBNL calculated annual national water savings (NWS) as the difference between two projections: a base case (without a WaterSense program) and the WaterSense program case. Positive values of NWS, which represent water savings, indicate that national annual water consumption (AWC) under the WaterSense program is less than the AWC projected for the base case.

$$NWS = AWC_{Base} - AWC_{WS}$$

Where:

NWS = national water savings,

AWC_{Base} = annual water consumption for a base-case projection, and

AWC_{WS} = annual water consumption given the WaterSense program.

Cumulative water savings are the sum of annual national water savings throughout the forecast period, which extends 30 years from the date the WaterSense-labeled products first were sold (January 1, 2010). The calculation is represented by the following equation:

$$NWS_{Cumulative} = \sum NWS_y$$

Where:

NWS = national water savings, and

y = year.

LBNL calculated the national AWC by multiplying the number, or stock, of products (by vintage) by their use frequency and by their unit water consumption (also by vintage). The calculation of national AWC is represented by the following equation:

$$AWC_y = \sum \left(STOCK_V \times UWC\right)_V \times FREQUENCY \times Days / Year$$

Where:

AWC_y = national water consumption each year in million gallons, summed over vintages of the product stock,

y = year,

$STOCK_v$ = stock of product (millions of units) of vintage V that survive in the year for which AWC is being calculated,

$FREQUENCY$ = annual use events per each product type as a function of building type,

$Days/Year$ = the number of working days for a given building type per year,

UWC_V = unit water consumption measured in gallons per flush or gallons per minute for the year in which the product was purchased, and

v = year in which the product was purchased as a new unit (vintage).

The stock of a product depends on annual shipments and the lifetime of the product. LBNL projected product shipment distributions under the base case and the WaterSense program case.

3 DATA INPUTS

This section describes the data inputs LBNL used to calculate national water savings attributable to the WaterSense CI program. As noted above, shipments are driven by the market segments of new construction and replacements.

3.1 Shipments

Total numbers of toilets and urinals shipped to nonresidential facilities before 2011 were obtained from industry reports. Table 1 lists the data obtained regarding the total number of fixtures shipped within or imported to the United States for various years. Past 2011, the shipments model described previously was used to estimate shipments. PRV shipments data was not available, so LBNL estimated shipments based on information gathered from industry experts.

Table 1 Numbers of Toilets and Urinals Shipped to Nonresidential Locations

Year	U.S. Shipments and Imports (thousands of units)	
	Toilets	Urinals
1992	1,728	233
1997	1,888	303
2002	1,923	346
2005	2,400	Data not provided
2006	2,622	343
2007	3,046	303
2008	2,795	292
2009	2,618	275
2014	2,771	284

Source: Catalina Research. 2007. *U.S. Toilet Market Profile;* Catalina Research, 2009. *U.S. Toilet and Toilet Seat Market Trends*.

3.1.1 Products in New Construction

LBNL used the rate of new commercial construction and employment data to develop the rate of product purchase for new installations. Table 2 shows forecasts of new commercial floorspace and existing (surviving) floorspace from the Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) for 2010.* The AEO predicted that new construction

* The methods underlying AEO forecasts are described at http://www.eia.doe.gov/oiaf/analysispaper/forecast_eval.html. (Last accessed September 20, 2010.)

will slow after 2008. A slowdown in new construction shifts the primary demand for water-conserving products to product replacements in surviving floorspace.

Table 2 Forecast of New and Surviving Nonresidential Floorspace

Year	New Floorspace (billion sq. ft)	Surviving Floorspace (billion sq. ft)	Year	New Floorspace (billion sq. ft)	Surviving Floorspace (billion sq. ft)
2004	2.2	70.8	2020	2.3	88.8
2005	2.2	72.2	2021	2.3	90.1
2006	2.3	73.5	2022	2.3	91.3
2007	2.4	74.9	2023	2.3	92.6
2008	2.4	76.4	2024	2.3	93.9
2009	2.2	77.9	2025	2.4	95.1
2010	1.8	79.2	2026	2.4	96.4
2011	1.6	80.1	2027	2.4	97.6
2012	1.6	80.7	2028	2.4	98.9
2013	1.7	81.4	2029	2.5	100.2
2014	1.9	82.1	2030	2.5	101.5
2015	2.0	83.0	2031	2.5	102.8
2016	2.1	84.1	2032	2.5	104.1
2017	2.2	85.2	2033	2.5	105.4
2018	2.2	86.4	2034	2.5	106.7
2019	2.3	87.6	2035	2.6	107.9

Source: Annual Energy Outlook, 2010. Energy Information Administration: http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html, Table 5.

3.1.2 Replacement Products

The rate at which a type of product is replaced is determined by the product lifetime. We know, for instance, that a certain percentage of installed flushometer valve toilets will be replaced each year as they reach the ends of their lifetimes. For the purposes of this analysis, the survival function is normalized using lifetimes obtained from industry experts, as shown in Table 3.

Table 3 Minimum, Average, and Maximum Lifetimes of Fixtures

Lifetime (years)	Toilets	Urinals	Pre-Rinse Spay Valves
Minimum	10	10	3
Average	20	20	5
Maximum	30	30	7

LBNL used a triangular retirement distribution to generate survival functions based on the parameters given in Table 3. The distribution provides that no products are retired before their minimum and all are retired by their maximum lifetimes.

3.2 Product Usage

LBNL used plumbing codes and building occupation data to estimate the usage per unit for the three products in each type of CI enterprise. LBNL used two methods of estimation: one for flushometer valve toilets and urinals, and another for pre-rinse spray valves. All the estimates depend on assumptions regarding the numbers and types of CI enterprises in the United States.

3.2.1 Toilets and Urinals

For flushometer valve toilets and urinals, LBNL combined the number of CI enterprises with the minimum fixture requirements stipulated in plumbing codes (Appendix A). For pre-rinse spray valves, LBNL calculated the number of restaurants and the CI enterprises nationwide that have kitchens. See sections 2.1.2 and 2.1.3 for a detailed explanation of these calculations.

3.2.2 Pre-Rinse Spray Valves

Assuming that all commercial- or institutional-grade kitchens have at least one pre-rinse spray valve, the quantity of pre-rinse spray valves is at a minimum the number of restaurant and institutional kitchens nationwide. LBNL found three different estimates for food service enterprises. To be consistent with the data used for other building types, LBNL used the NAICS data for the number of food service buildings.

3.3 Frequency of Use

LBNL utilized the report *Waste Not, Want Not* (Pacific Institute, 2003a, b) for the frequency of use for all three WaterSense products in preparation for determining their combined national water consumption. Table 4 presents our estimated frequency of use for each product by type of enterprise. The differences in use frequency among enterprise types reflect hours of operation and variations among data sources (Pacific Institute, Koeller and Associates).

Table 4 Frequency of Use by Product and Type of Enterprise

Enterprise	Flushometer Valve Toilet (flushes/day)				Urinal (flushes/day)		Pre-Rinse Spray Valve (minutes/day)		
	Men	Women	Visitor	Student / Patient	Men	Visitor	Low	Median	High
Education	0.95	1.95	0.86	0.94	0.94	0.31	130	190	240
Food Sales	1.60	2.60	0.33		1.25	0.17	30	50	60
Food Service	1.60	2.60	0.33		1.25	0.17	30	50	60
Health Care	1.60	2.60	0.00	4.0	1.25	0.17	30	50	60
Lodging	1.60	2.60	0.33		1.25	0.17	30	50	60
Retail	1.60	2.60	0.13		1.25	0.17			
Office	1.60	2.60	0.33		1.25	0.17			
Public Assembly	1.60	2.60	0.33		1.25	0.17			
Public Order and Safety	1.60	2.60	0.33		1.25	0.17			
Religious Worship	1.60	2.60	0.33		1.25	0.17			
Service	1.60	2.60	0.33		1.25	0.17			

3.4 Water Consumption per Unit

There is no detailed inventory of products in use (in the stock) categorized by rate of water consumption. A given product's efficiency can be approximated, however, based on its age and the history of the product's water use efficiency. The daily or annual amount of water used by a given product depends on both its frequency of use and its water consumption per use, otherwise known as its water use efficiency. The water use efficiency of a fixture, fitting, or product depends on the date when it was manufactured, shipped, and installed, because technologies and standards have changed throughout the years. For ease of estimation, LBNL assumed that all fixtures manufactured in a given year fell within a range of efficiencies and also were shipped and installed in that year. Furthermore, LBNL assumed that all replacement products met the contemporary Federal standard. Savings are calculated based on the difference between the Federal standards and the WaterSense label efficiencies.

Flushometer valve toilets have been on the market since 1906.[†] The earliest models used 5 to 10 gallons of water per flush, an amount that has been reduced continually since then. The Energy Policy Act of 1992 mandated that by 1994 toilets manufactured for residential installations use a maximum of 1.6 gallons per flush. That same water use efficiency was to be phased in by 1997 for commercial installations. Table 5 lists the federally mandated maximum water use efficiencies for each of the three WaterSense products by the year the governing standard became effective.

Table 5 Unit Water Consumption for Toilets, Urinals, and Pre-Rinse Spray Valves

Product	Federal Standard Maximum Water Use	Effective Date of Standard	WaterSense Label Water Use
Flushometer valve toilet	1.6 gpf*	1/1/1997	1.28 gpf
Flushometer valve urinal	1.0	1/1/1994	0.5 gpf
Pre-rinse spray valve	1.6 gpm[†]	1/1/2006	1.28 gpm

Source: Vickers, 2001, DOE, EPA.
*gpf = gallons per flush.
[†] gpm = gallons per minute.

3.5 Base Case Efficiency versus WaterSense Policy Case Efficiency

We characterized quantities of new equipment entering the stock, along with market share by efficiency level. It is through market share and efficient technologies that government efforts such as the WaterSense program reduce water consumption. In calculating national water savings attributable to the WaterSense program, we compare the following two scenarios: Base Case and WaterSense Policy Case. The policy case scenario depends on the degree of market penetration of WaterSense products. This is an unknown which is likely to depend primarily on consumer awareness and water prices. For the model, the market penetration parameter has been estimated by industry experts. We present several Policy Case scenarios below, but the model currently uses the “Low” Case.

3.5.1 Toilets

Base Case

[†] www.sloanvalve.com.

We obtained quantities of toilets shipped from both publicly available and purchased data for the years 1987, 1992, 1997, and for 2002-2009 and forecasted through 2014 (Catalina Research, 2009; D&R International, 2005), as shown in Section 3.1. However, we have not yet obtained shipment-weighted water use efficiency data. Pending updated shipment weighted efficiency data, we used industry estimates for the residential toilet market. The water use efficiency of toilets is defined by gallons per flush (gpf). Toilet efficiency has changed dramatically since 1949, when most toilets required 5 to 7 gpf. Although the 1970s began with a predominance of 5-gpf toilets, by the end of the decade most toilets required 3.5 gpf. In anticipation of the 1994 federal standard of 1.6 gpf, manufacturers began producing high-efficiency toilets beginning in the latter half of the 1980s. Toilets that use 1.6 gpf, which began to gain market share in the 1990s, now represent the majority of toilets sold. As of 2001, 1.28-gpf toilets began to enter the market and by 2014 they are projected to represent 11 percent of the market for new toilets. Table 6 shows estimates of the percentages of toilet shipments by water use efficiencies for the years 1994 through 2009 and forecasted percentages for 2010 through 2030. These estimates represent a base case without the WaterSense program. These shipment weighted efficiencies were estimated by industry experts for residential toilets. The shipment weighted efficiencies will be updated as industry data specific to non-residential toilets are collected.

Table 6 Base Case Market Shares for Flushometer Toilet Efficiencies by Year (in percents)

Year	1.28 gpf*	1.6 gpf	3.5 gpf	Year	1.28 gpf*	1.6 gpf	3.5 gpf
1994	0%	40%	60%	2013	12%	88%	0%
1995	0%	50%	50%	2014	13%	87%	0%
1996	0%	60%	40%	2015	15%	85%	0%
1997	0%	90%	10%	2016	17%	83%	0%
1998	0%	100%	0%	2017	21%	79%	0%
1999	0%	100%	0%	2018	23%	77%	0%
2000	0%	100%	0%	2019	26%	74%	0%
2001	1%	99%	0%	2020	30%	70%	0%
2002	1%	99%	0%	2021	34%	66%	0%
2003	1%	99%	0%	2022	38%	62%	0%
2004	2%	98%	0%	2023	41%	59%	0%
2005	3%	97%	0%	2024	45%	55%	0%
2006	3%	97%	0%	2025	49%	51%	0%
2007	5%	95%	0%	2026	53%	47%	0%
2008	5%	95%	0%	2027	56%	44%	0%
2009	5%	95%	0%	2028	60%	40%	0%
2010	5%	95%	0%	2029	64%	36%	0%
2011	5%	95%	0%	2030	68%	32%	0%
2012	11%	89%	0%				

* gpf – gallons per flush

Policy Case

Table 7 shows possible scenarios for the flushometer valve toilets with efficiencies of 1.28 gpf. The "Low" column is an estimate for the percentage mix of market share for 1.28 flushometer valve toilets with the WaterSense program. The WaterSense base case assumes an additional two percentage points of market share over the base case without the WaterSense program. The low estimate of WaterSense shipments is estimated at 5 more percentage points than the base case. These estimates will be adjusted with data collected from manufacturers.

Table 7 Estimates of Base Case and Policy Case Percentages of 1.28 gpf Flushometer Toilets

Year	Base Case	Low	Year	Base Case	Low
2012	11%	16%	2022	38%	43%
2013	12%	17%	2023	41%	46%
2014	13%	18%	2024	45%	50%
2015	15%	20%	2025	49%	54%
2016	17%	22%	2026	53%	58%
2017	21%	26%	2027	56%	61%
2018	23%	28%	2028	60%	65%
2019	26%	31%	2029	64%	69%
2020	30%	35%	2030	68%	73%
2021	34%	39%			

3.5.2 Urinals

Base Case

We obtained quantities of urinals shipped from both publicly available and purchased data for the years 1987, 1992, 1997, and for 2002-2009 and forecasted through 2014 (Catalina Research, 2009; D&R International, 2005), as shown in Section 3.1. However, we have not yet obtained shipment-weighted water use efficiency data. Pending updated shipment weighted efficiency data, we used industry estimates for the residential toilet market. The water use efficiency of urinals is defined by gallons per flush (gpf). Urinal efficiency has changed since instances of continuous flow. In anticipation of the 1994 federal standard of 1.0 gpf, manufacturers began producing high-efficiency urinals beginning in the latter half of the 1980s. Urinals that use 1.0 gpf, which began to gain market share in the 1990s, now represent the majority of toilets sold. As of 2001, 0.5-gpf urinals began to enter the market and by 2012 they are projected to represent 18 percent of the market for new urinals. Table 8 shows estimates of the percentages of urinal shipments by water use efficiencies for the years 1994 through 2009 and forecasted percentages for 2010 through 2030. These estimates represent a base case without the WaterSense program. These shipment weighted efficiencies were estimated by industry experts for plumbing fixtures. The shipment weighted efficiencies will be updated as industry data specific to urinals are collected.

Table 8 Base Case Market Shares for Urinal Efficiencies by Year (in percents)

Year	0.5 gpf and less*	1 gpf	1.5 gpf	3.5 gpf	Year	0.5 gpf and less*	1 gpf	1.5 gpf	3.5 gpf
1994	0%	20%	71%	9%	2013	18%	82%	0%	0%
1995	0%	30%	64%	6%	2014	19%	81%	0%	0%
1996	0%	40%	57%	3%	2015	21%	79%	0%	0%
1997	0%	100%	0%	0%	2016	24%	76%	0%	0%
1998	1%	99%	0%	0%	2017	28%	72%	0%	0%
1999	2%	98%	0%	0%	2018	32%	68%	0%	0%
2000	4%	96%	0%	0%	2019	36%	64%	0%	0%
2001	5%	95%	0%	0%	2020	39%	61%	0%	0%
2002	7%	93%	0%	0%	2021	43%	57%	0%	0%
2003	8%	92%	0%	0%	2022	47%	53%	0%	0%
2004	9%	91%	0%	0%	2023	51%	49%	0%	0%
2005	11%	89%	0%	0%	2024	54%	46%	0%	0%
2006	12%	88%	0%	0%	2025	58%	42%	0%	0%
2007	14%	86%	0%	0%	2026	62%	38%	0%	0%
2008	15%	85%	0%	0%	2027	66%	34%	0%	0%
2009	17%	83%	0%	0%	2028	70%	30%	0%	0%
2010	18%	82%	0%	0%	2029	74%	26%	0%	0%
2011	18%	82%	0%	0%	2030	78%	22%	0%	0%
2012	18%	82%	0%	0%					

*includes waterless urinals

Table 9 Estimates of Base Case and Policy Case Percentages of 0.5 gpf Urinals

Year	Base Case	Low	Year	Base Case	Low
2010	18%	28%	2021	43%	47%
2011	18%	28%	2022	47%	51%
2012	18%	28%	2023	51%	55%
2013	18%	28%	2024	54%	58%
2014	19%	28%	2025	58%	62%
2015	21%	28%	2026	62%	66%
2016	24%	28%	2027	66%	70%
2017	28%	32%	2028	70%	74%
2018	32%	36%	2029	74%	78%
2019	36%	40%	2030	78%	82%
2020	39%	43%			

3.5.3 Pre-Rinse Spray Valves

First introduced in 1985, pre-rinse spray valves have steadily reduced their flow rate of greater than 2 gallons per minute. In 2005, EPAct 2005 set a federal standard for a flow rate of 1.6 gallons per minute or less to take effect on January 1, 2006. (http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=f6d81be9cb1a10fe05ff02c8eb137c10&rgn=div6&view=text&node=10:3.0.1.4.19.15&idno=10)

Table 10 Base Case Market Shares for Pre-Rinse Spray Valve Efficiencies by Year (in percents)

Year	1.28 gpm*	1.6 gpm	2.0 or greater gpm	Year	1.28 gpm*	1.6 gpm	2.0 or greater gpm
1994	1%	4%	95%	2013	2%	98%	0%
1995	1%	16%	83%	2014	3%	97%	0%
1996	1%	26%	73%	2015	4%	96%	0%
1997	1%	35%	64%	2016	5%	95%	0%
1998	1%	43%	56%	2017	6%	94%	0%
1999	1%	50%	49%	2018	7%	93%	0%
2000	1%	56%	43%	2019	8%	92%	0%
2001	1%	62%	37%	2020	9%	91%	0%
2002	1%	66%	33%	2021	10%	90%	0%
2003	1%	70%	29%	2022	11%	89%	0%
2004	1%	74%	25%	2023	12%	88%	0%
2005	1%	74%	25%	2024	13%	87%	0%
2006	1%	99%	0%	2025	14%	86%	0%
2007	1%	99%	0%	2026	15%	85%	0%
2008	1%	99%	0%	2027	16%	84%	0%
2009	1%	99%	0%	2028	17%	83%	0%
2010	1%	99%	0%	2029	18%	82%	0%
2011	1%	99%	0%	2030	19%	81%	0%
2012	1%	99%	0%				

* gpm – gallons per minute

Table 11 Estimates of Base Case and Policy Case Percentages of 1.28 gpm Pre-Rinse Spray Valves

Year	Base Case	Low	Year	Base Case	Low
2010	1%	1%	2021	10%	15%
2011	1%	1%	2022	11%	17%
2012	1%	2%	2023	12%	18%
2013	2%	3%	2024	13%	20%
2014	3%	5%	2025	14%	21%
2015	4%	6%	2026	15%	23%
2016	5%	8%	2027	16%	24%
2017	6%	9%	2028	17%	26%
2018	7%	11%	2029	18%	27%
2019	8%	12%	2030	19%	29%
2020	9%	14%			

4 NATIONAL ANNUAL COST SAVINGS

The final output of the NWS-CI calculation is the monetary value of the water savings attributable to the purchase and installation of WaterSense-labeled products by the commercial and institutional sectors. The savings depend heavily on how much of the market is assumed to purchase WaterSense products. LBNL calculated the savings for operating costs only: for water and wastewater services. The calculation of savings did not include initial costs (purchase price and installation).[‡] We obtained the value of the water savings for a given product in a given sector by multiplying the estimated gallons of water saved by the $2010 prices for water and wastewater. We then summed the present values for each product and each sector in the base year and in each year of each product's lifetime. The values in future years were discounted, but not otherwise adjusted.

4.1 Water and Wastewater Prices

To determine the monetary value of the gallons of water saved by the WaterSense-CI program, LBNL used 2008 data for water and wastewater prices collected through a survey performed by Raftelis Financial Consultants in conjunction with the American Water Works Association (Raftelis/AWWA, 2008). The survey, which included approximately 280 water and 207 wastewater utilities, obtained prices separately for residential and nonresidential

[‡] Initial research shows that purchase price is not a factor for selection of WaterSense products.

customers and for each types of service. In both the water and wastewater surveys, the nonresidential sector is divided into four subsectors based on the average monthly volume of water delivered (or the size of the supply pipe). The subsectors are termed non-manufacturing, commercial, industrial 1, and industrial 2. We used data from the "commercial" category to estimate water and wastewater costs for CI customers.

The Raftelis/AWWA survey of water utilities includes the price each utility charges customers for using a given volume of water. Although the cost data are divided into fixed and volumetric charges, we utilized only the volumetric charge, because only that cost would be affected by a change in water consumption. The survey format is similar for wastewater utilities, except price refers to the price charged for collecting and treating a given volume of wastewater.

A sample of approximately 300 utilities is insufficient to serve as the basis for developing geographically based prices for all U.S. Census regions. Given the small sample, we calculated values at the level of major Census regions (Northeast, South, Midwest, and West). We followed three steps in calculating average prices per unit volume:

1. The price per unit volume for each surveyed utility was calculated by dividing the total volumetric cost by the volume delivered.
2. Next, an average price for each state was calculated by weighting each utility in a given state by the number of commercial customers it serves.
3. Finally, an average for each Census region was calculated by combining the state-level averages, weighting each value by the state's population. This third step helped reduce any bias in the sample caused by the relative under-sampling of large states.

Table 12 presents the results of the three-step calculation described above. The table includes the relative weight we assigned to each Census region when developing the nationwide average.

Table 12 Average Volumetric Prices for Water and Wastewater for the Commercial Sector

Region	Weight	Commercial Price ($/1,000 gallons) (2008$)	
		Water	Wastewater
Midwest	0.221	1.90	2.84
Northeast	0.182	2.55	3.12
South	0.361	2.39	3.58
West	0.227	3.02	3.76
National	1.000	2.45	3.36

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APPENDIX A – PLUMBING CODES FOR COMMERCIAL AND INSTITUTIONAL FACILITIES

Table A-1 Plumbing Code Usage by State, Territory

	UPC*	IPC†	NSP‡	Other		UPC	IPC	NSP	Other
Alabama		1			Montana	1			
Alaska	1	1			Nebraska	1	1		
Arizona	1	1			Nevada	1	1		
Arkansas				1	New Hampshire		1		
California	1				New Jersey			1	
Colorado	1	1			New Mexico	1	1		
Connecticut		1			New York		1		
D.C.		1			North Carolina		1		
Delaware		1			North Dakota	1			
Florida		1			Ohio		1		
Georgia		1			Oklahoma		1		
Hawaii	1				Oregon	1			
Idaho	1				Pennsylvania		1		
Illinois		1			Puerto Rico		1		
Indiana	1				Rhode Island		1		
Iowa	1	1			South Carolina		1		
Kansas	1	1			South Dakota	1			
Kentucky		1			Tennessee		1		
Louisiana		1			Texas	1	1		
Maine		1			U.S. Virgin Islands	1			
Maryland		1	1		Utah		1		
Massachusetts				1	Vermont		1		
Michigan		1			Virginia		1		
Minnesota	1				Wisconsin				1
Mississippi		1			Washington	1			
Missouri	1	1			West Virginia		1		
					Wyoming	1	1		

* UPC = Uniform Plumbing Code (International Association of Plumbing and Mechanical Officials, 2009).
† IPC = International Plumbing Code (International Code Council, 2009.)
‡ NSP = National standards for plumbing

Table A-2 Uniform Plumbing Code for Commercial and Institutional Facilities

Type of Building or Occupancy	Water Closets (fixtures per number of people) Male	Female	Urinals (fixtures per number of males)
Assembly Places (theatres, auditoriums, convention halls)—for permanent employee use	1: 1-15 2: 16-35 3: 36-55	1: 1-15 3: 16-35 4: 36-55	0: 1-9 1: 10-50 Add one fixture for each additional 50 males
	More than 55: add 1 fixture for each additional 40 persons		
Assembly Places (theatres, auditoriums, convention halls)—for public use	1: 1-100 2: 101-200 3: 201-400	3: 1-50 4: 51-100 8: 101-200 11: 201-400	1: 1-100 2:101-200 3: 201-400 4: 401-600 More than 600: add 1 fixture for each additional 300 males
	More than 400: add 1 fixture for each additional 500 males and 1 for each additional 125 females		
Dormitories (schools or labor)	1 per 10	1 per 8	1 per 25 More than 150: add 1 fixture for each additional 50 males
	Add 1 fixture for each additional 25 males (over 10) and 1 for each additional 20 females (over 8)		
Dormitories—for staff use	1: 1-15 2: 16-35 3: 36-55	1: 1-15 3: 16-35 4: 36-55	1 per 50
	More than 55: add 1 fixture for each additional 40 persons		

Type of Building or Occupancy	Water Closets (fixtures per number of people) Male	Female	Urinals (fixtures per number of males)
Hospital Waiting Rooms	1 per room		1 per room
Hospitals—for employee use	1: 1-15 2: 16-35 3: 36-55	1: 1-15 3: 16-35 4: 36-55	0: 1-9 1: 10-50 Add 1 fixture for each additional 50 males
	More than 55: add 1 fixture for each additional 40 persons		
Hospitals—individual rooms	1 per room		
Hospitals—ward rooms	1 per 8 patients		
Institutional—other than hospitals or penal institutions (on each occupied	1 per 25	1 per 20	0: 1-9 1: 10-50 Add 1 fixture for each additional 50 males
Institutional—other than hospitals or penal institutions (on each occupied floor)—for employee use	1: 1-15 2: 16-35 3: 36-55	1: 1-15 3: 16-35 4: 36-55	0: 1-9 1: 10-50 Add 1 fixture for each additional 50 males
	More than 55: add 1 fixture for each additional 40 persons		
Office or Public Buildings	1: 1-100 2: 101-200 3: 201-400	3: 1-50 4: 51-100 8: 101-200 11: 201-400	1: 1-100 2: 101-200 3: 201-400 4: 401-600 More than 600: add 1 fixture for each additional 300 males
	More than 400: add 1 fixture for each additional 500 males and 1 for each additional 150 females		
Office or Public Buildings—for employee use	1: 1-15 2: 16-35 3: 36-55	1: 1-15 3: 16-35 4: 36-55	0: 1-9 1: 10-50 Add one fixture for each additional 50 males
	More than 55: add 1 fixture for each additional 40 persons		

Type of Building or Occupancy	Water Closets (fixtures per number of people) Male	Water Closets (fixtures per number of people) Female	Urinals (fixtures per number of males)
Restaurants, Pubs, and Lounges	1: 1-50 2: 51-150 3: 151-300	1: 1-50 2: 51-150 4: 151-300	1: 1-150 More than 150: add 1 fixture for each additional 150 males
	More than 300: add 1 fixture for each additional 200 persons		
Schools—for staff use (all schools)	1: 1-15 2: 16-35 3: 36-55	1: 1-15 2: 16-35 3: 36-55	1 per 50
	More than 55: add 1 fixture for each additional 40 persons		
Nurseries (day care facilities)	1: 1-20 2: 21-50		
	More than 50: add 1 fixture for each additional 50 persons		
Elementary Schools	1 per 30	1 per 25	1 per 75
Secondary Schools	1 per 40	1 per 30	1 per 35
Others (colleges, universities, adult centers)	1 per 40	1 per 30	1 per 35
Worship Places—educational and activity facilities	1 per 150	1 per 75	1 per 150
Worship Places—principal assembly places	1 per 150	1 per 75	1 per 150

Source: Uniform Plumbing Code. International Association of Plumbing and Mechanical Officials, 2009.

Table A-3 International Plumbing Code for Commercial and Institutional Facilities

Classification	Description	Water Closets		Urinals
		Male	Female	
Assembly	Nightclubs	1 per 40	1 per 40	
	Restaurants	1 per 75	1 per 75	
	Theaters, Halls, Museums, etc.	1 per 125	1 per 65	
	Coliseums, arenas (< 3K seats)	1 per 75	1 per 40	
	Coliseums, arenas (≥3K seats)	1 per 120	1 per 60	
	Churches	1 per 150	1 per 75	
	Stadiums (< 3K seats)	1 per 100	1 per 50	
	Stadiums (≥ 3K seats)	1 per 150	1 per 75	
	Business	1 per 50		
	Educational	1 per 50		
	Passenger terminals and transportation facilities	1 per 500		
Institutional	Residential care	1 per 10		
	Hospitals, ambulatory nursing home patients	1 per room		
	Day nurseries, sanitariums, nonambulatory nursing home patients, etc.	1 per 15		
	Employees, other than residential care	1 per 25		
	Visitors, other than residential care	1 per 75		
	Prisons	1 per cell		
	Asylums, reformatories, etc.	1 per 15		
Retail	Mercantile	1 per 500		
Residential	Hotels, motels	1 per guestroom		
	Lodges	1 per 10		
	Dormitories	1 per 10		

Source: International Plumbing Code. International Code Council, 2009.

Table A-4 National Standard Plumbing Code for Commercial and Institutional Plumbing Facilities

Classification	Use Group	Description	No. of Persons of Each Sex	Water Closets Male	Water Closets Female	Urinals
Assembly	A-1	Theatres and other buildings for the performing arts and motion pictures usually with fixed seats	1 – 50 51 – 100 101 – 200 201 – 300 each add'l 300 over 300	1 add 1 add 1 add 1 add 1	1 add 1 add 2 add 1 add 2	
	A-2	Dance halls, nightclubs and for similar purposes.	1 – 25 26 – 50 51 – 100 each add'l. 200 over 100	1 add 1 add 0 add 1	1 add 1 add 2 add 2	
	A-3	Auditoriums without permanent seating, art galleries, exhibition halls, museums, lecture halls, libraries, restaurants other than nightclubs, food courts.	1 – 50 51 – 150 151 – 300 each add'l. 300 over 300	1 add 1 add 0 add 1	1 add 1 add 1 add 2	
	A-4 and A-5	Places of worship and other religious services. Churches without assembly halls.	1 – 1,000 over 1,000	1 add 1	1 add 1	
		Arenas, convention halls, outdoor assembly (grandstands, bleachers, coliseums, stadiums, amusement park structures, fair and carnival structures), passenger terminals.	1 – 100 101 – 200 201 – 400 each add'l. 200 up to 2,600 each add'l. 300 over 2,600	2 add 2 add 2 add 1 add 1	2 add 3 add 5 add 2 add 2	

Classification	Use Group	Description	No. of Persons of Each Sex	Water Closets Male	Water Closets Female	Urinals
		Recreational facilities: includes health spas, golf courses, public swimming pools and similar uses.	1 – 40 each add'l. 40 over 40	1 add 1	2 add 2	
Business	B	Buildings for the transaction of business, professional services, other services involving merchandise, office buildings, banks, light industrial and similar uses.	1 – 15 16 – 40 41 – 75 each add'l. 60 over 75	1 add 1 add 1 add 1	1 add 1 add 1 add 2	
Education	E	Educational facilities: Preschool, Day Care, Kindergarten	1 – 15 16 – 30 31 – 45 46 – 60 61 – 75 76 – 90 each add'l 30 over 90	1 add 1 add 1 add 1 add 1 add 1 add 1	1 add 1 add 1 add 1 add 1 add 1 add 1	
		Elementary Grades 1 – 5	1 – 25 26 – 50 51 – 75 76 – 100 each add'l. 50 over 100	1 add 1 add 1 add 1 add 1	1 add 1 add 1 add 1 add 1	
		Secondary Grades 6 – 12 and higher education facilities	1 – 30 31 – 60 61 – 90 91 – 120 each add'l. 60 over 120	1 add 1 add 1 add 1 add 1	1 add 1 add 1 add 1 add 2	

Classification	Use Group	Description	No. of Persons of Each Sex	Water Closets Male	Water Closets Female	Urinals
Institutional	I - 1	Six or more individuals in a supervised environment. Group homes. Alcohol and drug centers, convalescent facilities, hospital wards.	1 – 8 patients each add'l. 8 over 8	1 add 1	1 add 1	
	I - 2	Buildings, with six or more individuals, used for medical, surgical, psychiatric, nursing or custodial care.	1 water closet per room			
	I - 3	Buildings, with six or more persons under some restraint or security: a) Detention centers (short term).	1 per cell or 1 per 4 inmates			
		b) Prisons, jails and reformatories (long term).	1 per cell or 1 per 8 inmates			
Mercantile	M	a) Fixtures for customers in buildings occupied for display and sales purposes. Retail stores, service stations, shops, salesrooms, markets and shopping centers.	1 – 50 51 – 150 151 – 300 each add'l. 300 over 300	1 add 1 add 0 add 1	1 add 1 add 1 add 2	
		Fixtures for employees in buildings for the transaction of business, professional services, other services, involving merchandise, office buildings, banks, light industrial and similar uses.	1 – 15 16 – 40 41 – 75 each add'l. 60 over 75	1 add 1 add 1 add 1	1 add 1 add 1 add 2	

Classification	Use Group	Description	No. of Persons of Each Sex	Water Closets		Urinals
				Male	Female	
Residential	R-1	a) Hotel, motels	1 water closet per unit			
		b) Dormitories and boarding houses	1 – 20 each add'l. 20	2 add 1	2 add 2	

Source: "National Standard Plumbing Code.

APPENDIX B – BUILDING TYPE DEFINITIONS

Building Type Definitions from Commercial and Business Energy Consumption Survey

Building Type	Building Definition	Examples
Education	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	elementary or middle school, high school, college or university, preschool or daycare, adult education, career or vocational training, religious education,
Food Sales	Buildings used for retail or wholesale of food.	grocery store or food market, gas station with a convenience store, convenience store
Food Service	Buildings used for preparation and sale of food and beverages for consumption.	fast food, restaurant or cafeteria
Health Care (Inpatient)	Buildings used as diagnostic and treatment facilities for inpatient care.	hospital, inpatient rehabilitation
Health Care (Outpatient)	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	medical office (see previous column); outpatient rehabilitation, veterinarian
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	motel or inn, hotel, dormitory, fraternity, or sorority; retirement home; nursing home, assisted living, or other residential care; convent or monastery; shelter, orphanage, or children's

Building Type	Building Definition	Examples
		home; halfway house
Mercantile (Retail Other Than Mall)	Buildings used for the sale and display of goods other than food.	retail store; beer, wine, or liquor store; rental center; dealership or showroom for vehicles or boats; studio/gallery
Mercantile (Enclosed and Strip Malls)	Shopping malls comprised of multiple connected establishments.	enclosed mall; strip shopping center
Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	administrative or professional office; government office; mixed-use office; bank or other financial institution; medical office (see previous column); sales office; contractor's office (e.g., construction, plumbing, HVAC); non-profit or social services; research and development; city hall or city center; religious office; call center
Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	social or meeting (e.g. community center, lodge, meeting hall, convention center, senior center); recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports); entertainment or culture

Building Type	Building Definition	Examples
		(e.g., museum, theater, cinema, sports arena, casino, night club); library; funeral home; student activities center; armory; exhibition hall; broadcasting studio; transportation terminal
Public Order and Safety	Buildings used for the preservation of law and order or public safety.	police station; fire station; jail, reformatory, or penitentiary; courthouse or probation office
Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples).	No subcategories collected.
Service	Buildings in which some type of service is provided, other than food service or retail sales of goods	vehicle service or vehicle repair shop; vehicle storage/ maintenance (car barn); repair shop; dry cleaner or laundromat; post office or postal center; car wash; gas station; photo processing shop; beauty parlor or barber shop; tanning salon; copy center or printing shop; kennel

Source: Commercial and Business Energy Consumption Survey. 2003. Energy Information Administration.