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## Methodology for the national water savings models—indoor residential and commercial/institutional products, and outdoor residential products

Jonah Schein, Peter Chan, Yuting Chen, Camilla Dunham, Heidi Fuchs, Virginie Letschert, Michael McNeil, Moya Melody, Sarah Price, Hannah Stratton and Alison Williams

### ABSTRACT

Since 2006, the U.S. Environmental Protection Agency (EPA) has operated WaterSense® in partnership with manufacturers, utilities, and consumer groups. Similar to EPA's ENERGY STAR® role for energy-efficient products, WaterSense® employs a labeling system to identify water-efficient products, homes, and services. As of 2015, the WaterSense® program can claim credit for a total savings of 1.5 trillion gallons of water and \$32.6 billion in consumer water and energy bills. Savings are tracked in the National Water Savings (NWS) model that combines innovative analyses with methodologies established in the energy sector. Merging life-cycle cost and national impact analysis models, the NWS model estimates savings from a bottom-up accounting method for individual products. The model extends those savings to the national level by employing parameters such as frequency of product use by number of people and building type, product lifetime, stock accounting, and market saturation. The NWS model tracks the water and consumer monetary savings of WaterSense-labeled products for residential and commercial water use both indoors and out.

**Key words** | certification, efficiency, EPA, impact assessment, labeling, modeling, WaterSense®

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### INTRODUCTION

The U.S. Environmental Protection Agency (EPA) launched the WaterSense® labeling program in 2006 in response to the consumer and water utility need for clearly reliable products that reduce residential and commercial water consumption at the point of use. As part of WaterSense®, EPA established a process of product certification for the voluntary market-transformation program. In order to demonstrate the water saving capability of WaterSense® labeled products, EPA collected shipment, sales, and installation information from its partnership with manufacturers, retailers and distributors, homebuilders, irrigation professionals, and utilities.

With this information, Lawrence Berkeley National Laboratory (LBNL) developed mathematical models to estimate WaterSense® impacts as annual water savings (AWS) and the net present value (NPV) of the lifetime of savings from efficient indoor and outdoor products. No such method has been previously used to quantify water savings or project future savings.

The National Water Savings (NWS) models enable EPA to evaluate the success of its WaterSense® program, which includes labeled toilets, faucets, showerheads, and faucet aerators for the residential sector; and flushometer valve toilets, urinals, and pre-rinse spray valves for the commercial

and institutional (CI) sector. The only WaterSense® labeled outdoor product is the weather-based irrigation controller (WBIC). Aside from WBICs, EPA has only considered labeling products that have an efficiency level set by the Energy Policy Act (EPACT) of 1992 (or 2005 for pre-rinse spray valves). EPA places its WaterSense® label on products that are more efficient than the federal standards and meet a set of technical specifications for efficiency and performance. The NWS models forecast the amount of water that will be consumed by the residential and CI sectors with and without WaterSense® labeled products. In developing the Water Savings–Outdoor (WS–O) model, we assumed that residential outdoor water use and program savings differ from those associated with commercial outdoor water use. Commercial usage and savings were not estimated in this version of the model, however, because too few data were available. As a result, the estimates in the model based solely on the residential market are likely to be a conservative estimate of savings.

The section National water savings of this report summarizes the model calculations and inputs required for calculating the NWS under WaterSense®. Section Net present value reviews the inputs and NPV calculations for quantifying the monetary value of the water savings described in the section National water savings.

## NATIONAL WATER SAVINGS

The calculation of NWS associated with WaterSense® labeled products relies on three values: (1) number of products in use that are considered by the WaterSense program for labeling; (2) market share of products by water efficiency level or type; and (3) water saved annually, or unit water savings (UWS), for more efficient products compared to products covered by federal standards. For indoor products, the base case assumes federal standards in lieu of WaterSense® labeled products. The usage for all non-efficient products in both the base and policy cases is also set at a level used in Federal rulemakings which have not been changed since 1992 with EPACT. While this results in overly-conservative estimates (many plumbing products enjoy long life expectancy with values observed in the field still exceeding the levels specified by EPACT), it

ensures that the results of the analysis report only the savings attributable to the WaterSense® program. Using average field data for plumbing products covered by EPACT could inadvertently include savings that are also attributable to federal standards. Since WBICs have no existing federal standards, the base case assumes a greater saturation of timer irrigation controllers. We derived the number of both indoor and outdoor units in use by applying an accounting method to product shipments and lifetimes. The market share by efficiency and type depends on base case and policy case projections of product or efficiency penetration. The UWS is based on presence of the product and the amount of water savings possible.

We calculate both annual NWS and cumulative NWS throughout the period of interest, which extends from initiation of the WaterSense® program for each product (2007 for residential indoor products, 2009 for commercial indoor products, and 2011 for residential outdoor products) through 2030. Positive values of NWS represent water savings, meaning that national water use under the WaterSense® program is lower than in the base case.

### Definition

Annual NWS ( $NWS_y$ ) is calculated as the difference between two projections of AWS: a policy case (with the WaterSense® program) and a base case (without the WaterSense® program).

$$NWS_y = AWS\_WS_y - AWS\_base_y$$

where:

$NWS$  = annual national water savings,

$AWS\_WS$  = annual water savings in the policy case, and

$AWS\_base$  = annual water savings in the base case.

We describe further the calculation of national AWS in the section National annual water savings.

Cumulative water savings are the sum of each annual NWS throughout the projected period (first year of shipments to 2030). This calculation is represented by the following equation:

$$NWS_{cumulative} = \sum_{i=shipment\ start\ year}^{2030} NWS_y$$

## Inputs to the calculation

In developing inputs to the models, we consulted numerous sources, including those described in [McNeil et al. 2008](#); [Dunham et al. 2009](#); [Melody et al. 2014](#); [Williams et al. 2014](#), and [Williams et al. 2016](#). Characterization of the NWS calculation begins with the initial inputs to the model. The inputs for calculating NWS are:

- shipments (the section Shipments);
- product stock ( $stock_v$ ) (the section Product stock);
- AWS per unit ( $UWS$ ) (the section Annual water savings per unit); and
- national annual water savings ( $AWS$ ) (the section National annual water savings).

## Shipments

Shipments of products include both shipments to new construction and shipments to existing homes or CI buildings.

$$Shipments = ShipNC + ShipExist$$

or

$$ShipExist = Shipments - ShipNC$$

where:

$Shipments$  = total shipments of products,

$ShipNC$  = shipments to new construction, and

$ShipExist$  = shipments to existing homes or CI buildings.

Total shipments of products are based on data collected from manufacturers by EPA as part of the WaterSense® program starting in 2006, or the year that products began to earn the WaterSense® label. Industry experts, U.S. Census data, and new building growth rates from the Annual Energy Outlook (AEO) provided information about product saturations prior to 2006 ([U.S. Census Bureau 1998–2013](#); [U.S. EIA 2014](#)).

*Indoor residential and indoor commercial/institutional.* Energy Information Administration's (EIA's) energy consumption surveys of housing characteristics and commercial building characteristics are used in a stock

model to estimate the existing number of products per housing or building unit. ([U.S. EIA 2005](#); [U.S. EIA 2009](#)) We determine the portion of shipments replacing old products by subtracting products going to new construction from total shipments. To determine the rate of product saturation in new construction, we used the rate of new residential and commercial building construction from EIA's Annual Energy Outlook (AEO) ([U.S. EIA 2014](#)) AEO also provides the rate of new commercial construction correlated with employment data. This correlation is used with plumbing code product requirements dependent on occupancy to develop the rate of product purchase for new CI installations. A slowdown in new construction of new homes or CI buildings shifts the primary demand for water-conserving products to product replacements in surviving homes or existing CI floor space.

*Outdoor residential.* Shipments to new construction are calculated by multiplying the number of new homes by the percentage of new homes that have automatic sprinkler systems. For the national level, we derived data on new homes in a given year from U.S. Census information contained in the biennial American Housing Survey ([U.S. Census 2013](#)). For the state level, we derived annual data on new homes in the three states from decennial [U.S. Census Bureau Housing and Household Economic Statistics Division data from 1980–2000](#) and from the Census Bureau's annual American Community Survey (ACS) data from [2010–2014](#) ([U.S. Census 2010–2014](#)). The housing stock data from those years were interpolated for intervening years to complete a time series for 1979–2014; for single-family and multi-family, the number of new homes is obtained with the number of new building permits issued in each of the three states, while for mobile homes, the differences in housing stock between years were used to estimate numbers of new homes ([U.S. Census 1960–2014](#); [U.S. Census 2011](#); [U.S. Census 2014](#)). The trend in the 2010–2014 housing stock data provided by ACS 5-Year Estimates is used to extrapolate the 2015–2030 housing stock data.

The percentage of homes that have automatic irrigation systems, both at the national and state level, is developed from the EIA's Residential Energy Consumption Survey

(RECS). We accessed the most recent data for this information, derived from the 2005 RECS (U.S. EIA 2005).

$$ShipNC = NewHomes \times Sprinkler$$

where:

*NewHomes* = number of new homes in a given year, and  
*Sprinkler* = percent of new homes that have automatic irrigation systems.

Shipments to existing homes, as expressed in the model, currently represent simply the difference between total shipments and shipments to new construction.

$$ShipExist = ShipRep + ShipAdd$$

or

$$ShipExist = Shipments - ShipNC$$

where:

*ShipRep* = shipments to existing homes to replace failed controllers, and  
*ShipAdd* = shipments to existing homes that previously had no controllers.

### Product stock

The stock of products for any given year represents the sum of all the stock of stipulated vintages that continue to function. The rate at which a type of product is replaced is determined by the product lifetime. Stock also can be expressed as the product of shipments of given vintages and the percentage survival for each vintage.

$$Stock_y = \sum Stock_v$$

$$Stock_y = \sum (Shipments_{v,x} Surv_v)$$

where:

*Stock<sub>v</sub>* = stock of a given vintage surviving in a given year,  
*Surv<sub>v</sub>* = percentage of units of a given vintage surviving in a given year, and  
*y* = year.

*Indoor residential and indoor commercial/institutional.* The rate at which a type of product is replaced is determined by product lifetime. For the purposes of this analysis, the survival function is normalized using lifetimes obtained from industry experts. We used a triangular retirement distribution to generate survival functions for indoor products (see Table A-1 of Appendix A; Appendix A is available with the online version of this paper). The distribution assumes that no products are retired before their minimum and all are retired by their maximum lifetimes. Product stocks change from product retirements due to lifetime and new construction (see Table A-1 of Appendix A). For the purposes of this analysis, the survival function is normalized using lifetimes obtained from industry experts. Lifetime is used to determine product savings between the base case and the policy case. Federally mandated maximum water use efficiencies are given in Table A-2 of Appendix A.

*Outdoor residential.* We developed the inputs to the survival function of units based on a variety of sources (see Table A-3 of Appendix A). Approximately half of the weather and soil moisture sensor-based irrigation controller market is expected to have site-based sensors that may fail sooner than the controller itself. Such failures essentially default a controller to a clock timer controller. While a weather or soil moisture sensor-based controller might still be preferable to a traditional clock timer controller in this instance due to their ability to default to historic patterns (thus ensuring they are properly set), it would be inaccurate to assume that controllers with failed sensors would deliver the same savings as fully functional ones, so they are considered retired for purposes of this analysis. To account for this, we estimated a median lifetime of seven years (10 years for the half of controllers without site-based sensors and three years for the half of controllers with site-based sensors). We also estimated a minimum lifetime of three years and a maximum of 15 years. Like for indoor products, this distribution assumes that no products are retired before their minimum lifetime and all are retired by their maximum lifetimes (see Figure A-1 of Appendix A). In future iterations of the model, the survival function could be disaggregated by controller type.

A summary of estimated product stock for all product types is included in Table A-4 of Appendix A.

### Annual water savings per unit

The UWS is the difference in water consumption between the policy case from the base case, or the product of the policy-base case savings ratio on the unit water consumed (UWC). The UWC is based on market share data and the existing efficiency mix of the stock. 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.

*Indoor residential.* For indoor products, savings are calculated based on the difference between the federal standards and the WaterSense® label efficiencies. By taking the difference between the Federal standards and the WaterSense® label efficiencies, no baseline use is ever calculated. Additionally, the model is conservative in its estimate of savings in that it assumes that all replaced stock are no more efficient than the current federal standards. The UWC is determined by the end-use water consumption (EUWC) divided by the number of products in stock.

$$UWS(v) = UWC_{BaseCase}(v) - UWC_{PolicyCase}(v)$$

$$UWC_v = \frac{EUWC_v}{Stock_v} \times \frac{Days}{Year}$$

where:

$UWS$  = unit water saved (in gallons/product),

$UWC$  = unit water consumption (in gallons/product),

$EUWC$  = end-use (i.e. toilet) water consumption for homes (in gallons/day),

$Stock_v$  = stock of all vintages surviving, and

$v$  = product vintage.

*Indoor commercial/institutional.* The UWC for indoor commercial products is estimated for each year by multiplying product water efficiencies and the efficiency market share for each product. The historical efficiency market share was estimated by industry experts (Gleick et al. 2003b; Koeller 2005; Koeller 2009). Since 2006 (or the first year for which WaterSense® labeled products in the individual product category are shipped), the efficiency market share is determined by product shipments information.

*Outdoor residential.* The equation used to derive UWS is outlined below. Water consumption values come from different sources for the nation as a whole and for three separate states: California, Florida, and Texas (see Appendix A, Table A-7) (AWWARF 1999; Gleick et al. 2003a; Milesi et al. 2005; Mayer et al. 2009; Milesi et al. 2009; NWF 2010; DeOreo et al. 2011; Hermitte & Mace 2012; Cabrera et al. 2013; Friedman et al. 2013; Romero & Dukes 2013; Aquacraft 2014; NRDC 2014). No baseline water use amount is calculated; savings are determined by a ratio of controller efficiencies (Williams et al. 2016).

$$UWS_v = EUWC_{cont_v} \times \%Savings_v \times Days/Year$$

where:

$UWS$  = annual unit water savings (in gallons/year),

$EUWC_{cont}$  = end-use (i.e. irrigation) water consumption for homes having irrigation controllers (in gallons/day), and

$\%Savings$  = percent of water savings from controller mix under base case or policy case.

It is assumed that only one irrigation controller serves each household; hence the EUWC is equivalent to the per-unit consumption.

### End-use water consumption

*Indoor residential.* The next equation from the Residential End Uses of Water Study (REUWS) 2016 study exemplifies the EUWC calculation for indoor residential products (toilets in this example) in gallons per household per day (Water Research Foundation 2016). Between 1998 and 2010, the EUWC was scaled to account for the variation in water use. Similar equations estimate other indoor products (see Appendix A, Table A-5 for parameters and their values) (Aquacraft 2014).

$$EUWC_{toilet} = 11.485 \times HS^{0.656} \times (T)^{-0.144} \\ \times (C)^{-0.184} \times (ATHOME)^{0.244} \times PSQFT^{0.060} \times SR^{-0.054} \\ \times e^{(-0.598(ULTF) - 0.144(RENT))}$$

where:

*EUWC* = end-use water consumption in gallons per household per day,

*HS* = number of persons residing in the home,

*T* = number of 13–17 year olds residing in the home,

*C* = number of 12 year olds and younger residing in the home,

*ATHOME* = number of people at home during the day,

*PSQFT* = parcel size,

*SR* = sewer rate,

*e* = base of the natural logarithm (2.71),

*ULTF* = presence of efficiency toilets/flushes, and

*RENT* = households that rent as opposed to own.

*Indoor commercial/institutional.* For commercial indoor products, the daily or annual amount of water used by a given product depends on both its water consumption per use and its frequency of use. For the UWC of a fixture, fitting, or product, we assumed that all replacement products meet the current federal standard. Savings are calculated based on the difference between the federal standards and the WaterSense® label efficiencies. 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. We used the report *Waste Not, Want Not* (Gleick et al. 2003a; Gleick et al. 2003b) to determine the frequency of use for all three commercial products in order to calculate their combined national water consumption. The differences in frequency of use among enterprise types reflect hours of operation and variations among data sources (Gleick et al. 2003a; Gleick et al. 2003b; Koeller & Co. 2005). (See Appendix A, Table A-6 for the estimated frequency of use for each product by type of enterprise.)

*Outdoor residential.* Because there is no federal standard for irrigation controllers, several values were initially determined for the EUWC of outdoor irrigation water use for 2010 (see Appendix A, Table A-7). Instead of relying on single point values, the ability to run the model using several scenarios for EUWC can yield range estimates that may be more reflective of real-world variation.

For purposes of reporting accomplishments and numbers associated with the WaterSense® program, EPA typically uses the number of households from RECS 2009 (U.S. EIA 2009).

Values for years other than 2010 were scaled from the ratio of 2010 literature review estimates to a REUWS study (AWWARF 1999) equation estimate. The equation used for calculating EUWC follows. (See Appendix A, Table A-8 for a description of the data inputs.)

$$EUWC = 0.046 * MPW^{-0.887} \times HSQFT^{0.654} \times LOTSIZE^{0.237} \times e^{1.116(SPRINKLER)+1.039(POOL)}$$

where:

*EUWC* = end-use (i.e. outdoor/irrigation) water consumption in gallons per household per day,

*MPW* = marginal price of water (\$/kgal),

*HSQFT* = average home square footage,

*LOTSIZE* = size of lot (average in square feet),

*e* = base of the natural logarithm (2.718282),

*SPRINKLER* = fraction of customers having in-ground sprinkler systems, and

*POOL* = fraction of customers having swimming pools.

EUWC represents consumption for the housing stock. We calculated EUWC for new construction separately from the EUWC for stock by taking the ratio of the model results using the calculations of home square footage, lot size, and sprinklers for new construction to the model results using those values for stock.

EUWC is used to determine annual water consumption in a frozen efficiency case (see the section National annual water savings). In order to determine AWS for irrigation controllers, we determined a separate EUWC value for irrigation controllers based on the REUWS finding that homes that have irrigation timers use 47% more water than those without timers (AWWARF 1999).

### Percent savings

In order to calculate the AWS per irrigation controller (UWS), the EUWC for controllers is multiplied by the percent savings for the controller mix in the base case and

the policy case. The percent savings for the controller mix is the sum product of the market share of each controller type and the percent water savings attributable to each controller type:

$$\%Savings = \sum \%Share_{type} \times \%Savings_{type}$$

where:

$\%Savings$  = average percent water saved with a given controller mix,

$\%Share_{type}$  = percent of total controllers by type,

$\%Savings_{type}$  = average percent savings for each controller type, and

$type$  = type of controller (timer, WBIC, or SMS).

The market share of each controller type is determined from the total shipments of controllers, based on the equation below. (See Appendix A, Table A-9 for a description of the inputs.) Values for percentages of timers, WBIC, and SMS differ by year and between the base case and policy case.

$$\%Share_{type} = \frac{Shipments_{type}}{Shipments}$$

where:

$Shipments_{type}$  = annual shipments of each type of controller.

The percent savings by type is based on research conducted by Williams *et al.* (2014). The EUWC calculated for controllers is assumed to be based on the use of timers. Therefore, AWS for WBIC and SMS controllers refer to a baseline water use with a timer. The value for percent savings remains constant throughout the analysis period.

### National annual water savings

National AWS is the product of the AWS per unit and the number of units of each vintage. This calculation accounts for differences in unit water consumption from year to

year. The equation for determining AWS is:

$$AWS_y = \sum stock_v \times UWS_v$$

AWS is calculated separately for the base case and the policy case.

The model considers primarily water savings rather than water consumption, because it is not necessary to estimate the annual water consumption of all products in use to evaluate water savings from the program. The model, however, does produce estimates of annual water consumption for product end-use in a frozen efficiency scenario, the base case, and the policy case.

$$AWC_{frz_y} = Households \times EUWC_y \times Days/Year$$

$$\begin{aligned} AWC_{base_y} &= AWC_{frz_y} - \sum (stock_v \times UWS_{base_v}) \\ &= AWC_{frz_y} - AWS_{base_y} \end{aligned}$$

$$\begin{aligned} AWC_{WS_y} &= AWC_{base_y} - \sum (stock_v \times UWS_{WS_v}) \\ &= AWC_{base_y} - AWS_{WS_y} \end{aligned}$$

where:

$AWC_{frz}$  = annual water consumption in the frozen efficiency case (year of penetration of water using product),

$AWC_{base}$  = annual water consumption in the base case (without the WaterSense® program), and

$AWC_{WS}$  = annual water consumption in the policy case (with the WaterSense® program).

### NET PRESENT VALUE

The monetary value (NPV) of the reduced water costs associated with the water savings in the WaterSense® was calculated. The models do not include the total installed cost, the difference between total installed cost, and non-operating cost savings in the NPV savings calculation. Currently, the differences in purchase prices between efficient and non-efficient products appear to be minimal in relation to water cost savings (WCS). EPA may consider such an addition in the future if



equipment prices begin to vary between labeled and non-labeled products.

### Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is described by the following equation.

$$NPV = PVS - PVC$$

where:

$PVS$  = present value of savings in water costs, and

$PVC$  = present value of increase in total installed cost (including costs for product and installation).

The  $PVS$  was determined according to:

$$PVS = \sum^W CS_y \times DF_y$$

where:

$WCS$  = total annual savings in operating cost each year summed over vintages of the product stock,  $stock_v$ , and

$DF$  = discount factor.

We calculated the total annual savings in operating costs by multiplying the number, or stock, of the product (by vintage) by its per-unit  $WCS$  (also by vintage).

$$WCS_y = \sum stock_v \times UWCS_v$$

where:

$stock_v$  = stock of product (millions of units) of vintage  $v$  that survive in the year for which annual water consumption is being calculated,

$UWCS_v$  = annual per-unit savings in water cost,

$v$  = year in which the product was purchased as a new unit, and

$y$  = year in the projection.

The  $PVS$  was determined for each year from the initiation of the WaterSense® labeling program until 2030.

Savings were calculated as the difference between the policy case and the base case.

We calculated a discount factor ( $DF$ ) from the discount rate and the number of years between the present year (the year to which the sum is being discounted) and the year in which the costs and savings occur. The NPV is the sum over time of the discounted net savings.

### Inputs to the calculation

The inputs to calculation of the NPV are:

- annual per-unit savings in water and wastewater cost,
- shipments,
- equipment stock ( $stock_v$ ),
- total annual water cost savings ( $WCS$ ),
- discount factor ( $DF$ ), and
- present value of savings ( $PVS$ ).

The total annual savings in water costs are equal to the change in annual water costs (difference between base case and policy case) per unit multiplied by the projected shipments.

### Product stock

The stock of products in any given year depends on annual shipments and the lifetime of the controllers. The models track the number of units shipped each year. The lifetime of a unit determines how many units shipped in previous years survive in any given year. Products were assumed to have an increasing probability of failing as they age. The probability of survival as a function of years since purchase is termed the survival function. That function was described in the section Product stock.

### Annual water and wastewater cost savings per unit

We determined the per-unit annual savings in water costs by multiplying the per-unit annual savings in water consumption by the price of water and wastewater. Prices and price trends were developed for water and wastewater services.

Equations for estimating the per-unit annual water consumption for the base case and the policy case were

presented in the section National annual water savings. To determine the monetary value of the gallons of water saved by the labeling program, data were used from a survey on water and wastewater prices conducted by Raftelis Financial Consultants in conjunction with the American Water Works Association (Raftelis Financial Consultants/American Water Works Association 2015). The survey, which included approximately 315 water and 182 wastewater utilities, obtained prices separately for residential and nonresidential customers for each type of service. In both the water and wastewater surveys, the residential sector is divided into four subsectors based on the average monthly volume of water delivered (or the size of the meter).

The Raftelis/AWWA survey of water utilities includes the price each utility charges customers for using a given volume of water. The survey format is similar for wastewater utilities, except that price refers to the price charged for collecting and treating a given volume of wastewater.

A sample of approximately 315 utilities is insufficient to serve as the basis for developing a finer resolution of 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). The average national water price is \$4.49 and the wastewater price is \$5.61, in 2014 dollars. (See Appendix A, Table A-10 for average prices for water and wastewater by census region; Appendix A is available with the online version of this paper.) We followed three steps in calculating average prices per unit volume (Fisher et al. 2008).

1. We calculated the price per unit for each surveyed utility by dividing the total cost by the volume delivered.
2. Next, we calculated an average price for each state by weighting each utility in a given state by the number of residential customers it serves.
3. Finally, we calculated an average for each census region 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.

To estimate the future trend for water and wastewater prices, we used data on the historic trend in the national water price index (US city average) from 1970 to 2015 from the U.S. Bureau of Labor Statistics Water and Sewerage

consumer price index (U.S. Bureau of Labor Statistics 2014). We extrapolated the future trend based on the linear growth from 1970 to 2015 and used the extrapolated trend to forecast prices through 2030.

### Savings in total annual water cost

The savings in total annual water cost for the policy case are the product of the annual per-unit savings in water cost attributable to the policy and the number of units of each vintage. This method accounts for the year-to-year differences in annual savings in water costs. The equation for determining the total annual savings in water cost for the policy case was presented in the section Definition.

### Discount factor

Monetary values in future years were multiplied by a DF to determine their present values. The DF is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_p)}}$$

where:

$r$  = discount rate,

$y$  = year of the monetary value, and

$y_p$  = year in which the present value is being determined.

The models can be run using any discount rate. Three-percent and a seven-percent real discount rates are recommended in accordance with the Office of Management and Budget's guidance to federal agencies on the development of regulatory analysis, particularly section E therein, *Identifying and Measuring Benefits and Costs*. The present year was defined as 2015 (U.S. OMB 2003).

### Present value of savings

The present value of annual savings in water costs is the difference between the base case and the policy case discounted to the present and summed from the initiation of the program to any given year through 2030. Savings re-present decreases in water costs associated with more products purchased under the policy case compared to the base case.

## CONCLUSION

Since the EPA launched the WaterSense program over 10 years ago in 2006, Americans have saved \$32.6 billion in water and energy costs. WaterSense® has also helped save 1.5 trillion gallons of water, which is more than the amount needed to supply all of the homes in California with water for a year. In addition to saving water, WaterSense® labeled products save the energy associated with treating, pumping, and heating water. Since 2006, WaterSense® labeled products saved energy equal to the amount used to power 19.4 million homes for a year, while preventing 78 million metric tons of associated greenhouse gas emissions.

This study describes the approach LBNL developed to estimate impacts of the U.S. EPA's WaterSense® labeling program for both indoor and outdoor water-consuming products. The models quantify the water savings and associated NPV attributable to the program on product and aggregated levels. The models' structure allows all inputs to be updated for continued tracking of the WaterSense® program's impact on the market over time, providing current feedback to the EPA, industry partners, and other stakeholders on the efficacy of the program. Further versions of the models might include product costs for fuller estimates of the NPV and include the impacts of reduced flows to water and wastewater utilities.

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