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DISCLAIMER

1 INTRODUCTION

This report describes the analytical models Lawrence Berkeley National Laboratory (LBNL) developed to estimate impacts of the U.S. Environmental Protection Agency's (EPA's) WaterSense® labeling program. The models assess national impacts for WaterSense labeled toilets, faucets, faucet aerators, showerheads, flushing urinals, commercial pre-rinse spray valves, and weather or soil moisture sensor-based irrigation controllers (WBICs) by analyzing national inputs for water use in residential and commercial/institutional (CI) markets. For irrigation controllers, LBNL's methodology also incorporates a scenario that evaluates impacts in three key large states that are considered to be the principal market for "smart" irrigation controllers: California, Florida, and Texas. The models estimate impacts for the water savings attributable to the program and the net present value (NPV) of the lifetime water savings from more efficient products.

LBNL developed the mathematical models to quantify the water and monetary savings attributable to the WaterSense labeling program for both indoor and outdoor products. The National Water Savings (NWS) models are spreadsheet tools with which the EPA can evaluate the success of its WaterSense program, which encourages buyers to purchase more efficient water-using products. WaterSense labelled indoor products include toilets, faucets, showerheads, and faucet aerators for the residential sector; and flushometer valve toilets, urinals, and pre-rinse spray valves for the CI sector. The current single WaterSense labeled outdoor product is the weather-based irrigation controller (WBIC). It should be noted that other than irrigation controllers, EPA has only considered labeling products that have an efficiency level set by the Energy Policy Act of 1992 (or 2005 in the case of 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 that do and do not use WaterSense-labeled products.[1]

This paper explains the data LBNL collected and the calculations it used to estimate the water savings associated with WaterSense-labeled products. The calculation of water savings relies on three values: (1) the number of products in use that are considered by the WaterSense program for labeling; (2) the market share of the products by water efficiency level or type; and (3) the water saved annually, unit water savings (UWS), for the more efficient products compared to products covered by federal standards. For indoor products, the base case assumes federal standards in lieu of all labeled water-consuming products LBNL modeled. The usage for all non-

[1] In developing the Water Savings – Outdoor (WS–O) model, LBNL 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. LBNL believes that the estimates in the model, which is based solely on the residential market, are therefore likely to be a conservative estimate of savings.

efficient products in both the base and policy case is also set at the federal standard. While this results in overly conservative estimated (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 more attributable to the federal standards than to WaterSense. Since WBICs have no existing federal standards, the base case assumes a greater saturation of timer irrigation controllers. LBNL derived the number of both indoor and outdoor units in use by applying an accounting method to product shipments and product 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. To quantify the monetary value of the water savings attributable to the WaterSense program, LBNL developed prices and price trends for water and wastewater services.

Section 2 of this report summarizes the model calculations and the inputs required for calculating the national water savings under WaterSense, while section 3 reviews the inputs and calculations for national net present value and describes the method used to develop residential and commercial water and wastewater prices and price trends.

2 NATIONAL WATER SAVINGS

LBNL calculates both annual NWS and cumulative NWS throughout the period of interest, which extends from initiation of the WaterSense program for each product to 2030.[2] Positive values of NWS represent water savings, meaning that national water use under the WaterSense program is lower than in the base case.

2.1 Definition

LBNL calculates annual NWS (NWS_y) as the difference between two projections of annual water savings (*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.

[2] The program for residential indoor products began in 2007, for commercial indoor products in 2009, and residential outdoor products began in late 2011. Shipments data were recorded the following year.

The calculation of national annual water savings is described further in section 2.2.4.

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.

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

2.2 Inputs to the Calculation

In developing inputs to the models, LBNL consulted numerous sources, including those described in Dunham *et al.* 2009, Melody *et al.* 2014, and Williams *et al.* 2014. Characterization of the NWS calculation begins with the initial inputs to the spreadsheet model. The inputs for calculating NWS are:

- shipments (section 2.2.1);
- product stock ($stock_v$) (section 2.2.2);
- annual water savings per unit (*UWS*) (section 2.2.3); and
- national annual water savings (*AWS*) (section 2.2.4).

2.2.1 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, US Census data, and new building growth rates from the Annual Energy

Outlook (AEO) provided information about product saturations prior to 2006.

Indoor Residential and Indoor CI

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. The portion of shipments replacing old products is determined from the difference between products going to new construction subtracted from total shipments. To determine the rate of product saturation in new construction, LBNL used the rate of new residential and commercial building construction from Energy Information Administration's (EIA's) Annual Energy Outlook (AEO). 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. 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. 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.[3]

[3] In response to drought conditions, in July 2015 California adopted an updated, more stringent Model Water Efficient Landscape Ordinance (MWELO). The updated Ordinance requires new or significantly rehabilitated landscape projects that are (1) homeowner installed and larger than 5,000 square feet, or (2) developer installed and larger than 2,500 square feet, use automatic irrigation controllers that utilize either ET or SMS technology. We do not take this into account in determining shipments. Thus, shipments in California (particularly for new construction) are likely on the conservative side.

$$ShipNC = NewHomes \times Sprinkler$$

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 spreadsheet 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.

2.2.2 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:

$Stock_v$	=	stock of a given vintage surviving in a given year,
$Surv_v$	=	percentage of units of a given vintage surviving in a given year,
y	=	year.

Indoor Residential and Indoor CI

The rate at which a type of product is replaced is determined by the product lifetime. For the purposes of this analysis, the survival function is normalized using lifetimes obtained from industry experts. LBNL used a triangular retirement distribution to generate survival functions for indoor products based on the parameters given in Table 1. The distribution assumes that no products are retired before their minimum and all are retired by their maximum lifetimes. 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.

Table 1 Minimum, Average, and Maximum Lifetimes of Fixtures

Lifetime (years)*	Tank-type Toilets	Faucets	Faucet Aerators	Shower-heads	Urinals	Pre-Rinse Spay Valves	Flushometer Valve Toilets
Minimum	10	5	5	5	10	3	10
Average	20	10	10	10	20	5	20
Maximum	30	15	15	15	30	7	30

*Industry experts

Table 2 lists the federally mandated maximum water use efficiencies for each of the indoor WaterSense products.

Table 2 Federal Standards for Indoor WaterSense Products

Product	Federal Standard Maximum Water Use	WaterSense Label Water Use
Showerhead	2.5 gpm* or 2.2 gpm**	2.0 gpm
Faucet		1.5 gpm
Gravity tank toilet	1.6 gpf†	1.28 gpf
Flushometer valve toilet		1.28 gpf
Flushometer valve urinal	1.0 gpm	0.5 gpf
Pre-rinse spray valve	1.6 gpm	1.28 gpm

Source: Vickers, 2001, DOE, EPA.
*gpm = gallons per minute
**flow rate difference depends on water pressure of 80 psi or 60 psi
†gpf = gallons per flush.

Outdoor Residential

We developed the inputs to the survival function of units based on a variety of sources listed in Table 3. 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, LBNL 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). LBNL 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 and all are retired by their maximum lifetimes. Figure 1 shows the probability of survival function used in our model. In future iterations of the model, the survival function could be disaggregated by controller type.

Table 3 Sources for Irrigation Controller Survival Function

Source	Estimated Lifetime (years)
Mayer *et al.* 2009	10
Manufacturer warranties	1 – 10
Market experts	10 – 15 for controllers; 2 – 4 years for site-based sensors

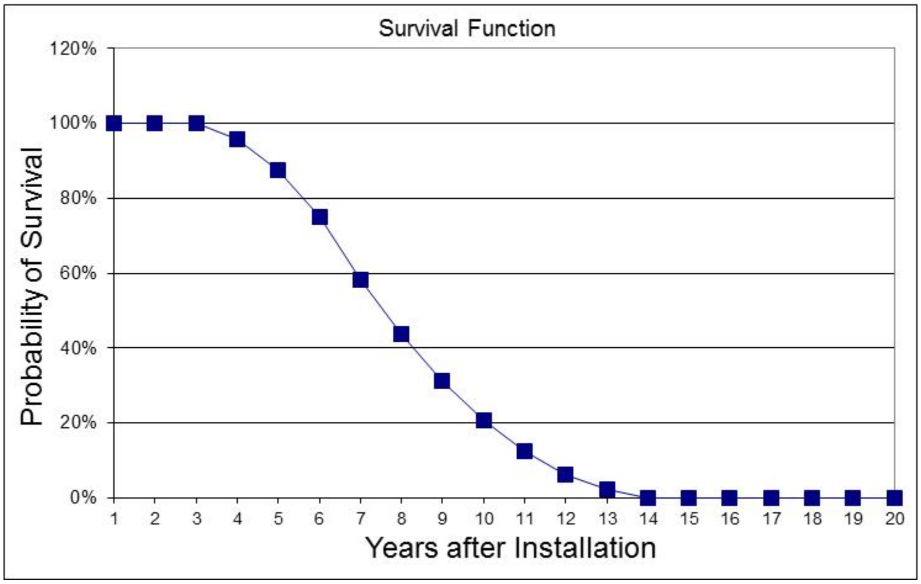

Figure 1 Probability of Survival of WBIC

2.2.3 Annual Water Savings per Unit

The unit water savings (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. The UWC is determined by the 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,
v	=	product vintage.

Indoor CI

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. Since 2006 or the first year for which WaterSense labeled products in the individual category are shipped, the efficiency market share is determined by product shipments information.

Outdoor Residential

The equation used to derive unit water savings is outlined below.

$$UWS_v = EUWC\_cont_v \times \%Savings_v \times Days/Year$$

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 end-use water consumption is equivalent to the per-unit consumption.

<u>End-Use Water Consumption</u>

Indoor Residential

The next equation from the REUWS 2016 study exemplifies the end-use water consumption calculation for indoor residential products (toilets in this example) in gallons per household per day. Between 1998 and 2010, the EUWC was scaled to account for the variation in water use. Similar equations estimate other indoor products.

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

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 under 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 (2.718282);
$ULTF$	=	presence of efficiency toilets/flushes; and
$RENT$	=	households that rent as opposed to own.

Inputs for the EUWC equation are shown in Table 4.

Table 4 End-Use Water Consumption Calculation - Stock (2010)

Parameter	Source	National Average (2010)	Units
Number of household members*		2.74	# persons
Number of 13-17 year olds*		1.18	# 13-17 yrs
Number of 12 years and under*	RECS 2009	1.53	# <= 12 yrs
Number of people at home during the day*		1.51	# persons
Number of people at work*		1.36	# persons
Sewer rate	Raftelis / AWWA	4.82	$ / kGal
Parcel size	American Housing Survey	11,108	Square feet
Presence of efficiency toilets/flushes*	REUWS	0.6	yes / no
Renter*	US Census	0.32	yes / no

Indoor CI

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, LBNL assumed that all replacement products met 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. LBNL used the report *Waste Not, Want Not* (Pacific Institute, 2003a,b) for the frequency of use for all three commercial products in preparation for determining their combined national water consumption. Table 5 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 5 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			

Outdoor Residential

Because there is no federal standard for irrigation controllers, LBNL initially determined several values for the end-use water consumption (EUWC) of outdoor irrigation water use for 2010, as described in Table 6. 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.

Table 6 End-Use Water Consumption Calculation - Stock (2010)

Parameter	Source	National	CA	FL	TX	Units
Public supply for domestic use + self-supplied withdrawals	USGS 2014 (Table 6)	27,400	4,042	1,644	2,309	million gallons/day
Option 1.1 Estimation (Number of Households from AEO and U.S. Census Bureau)						
Number of households	AEO 2014 and U.S. Census Bureau	112.9	13.5	8.9	9.7	million homes
Daily household water use	*Calculation*	*243*	*299*	*186*	*238*	*gal/day/ household*
Percent outdoor water use	Various	31[*]	48[**]	42[†]	34[‡]	percent
Daily household outdoor water use	*Calculation*	*76*	*144*	*79*	*81*	*gal/day/ household*
Percent of homes with pools	RECS 2009	10.1	15.0	22.7	8.3	percent
Percent increase in water use for homes with pools	AWWARF 1999 (Table D.8 and Equation D.7)	123	123	123	123	percent
Daily household irrigation water use (outdoor water use excluding pools)	***Calculation***	***68***	***121***	***62***	***73***	***gal/day/ household***
Option 1.2 Estimation (Numbers of Households from RECS 2009)						
Number of households	RECS 2009	113.6	12.2	7.0	8.5	million homes
Daily household water use	*Calculation*	*241*	*331*	*235*	*271*	*gal/day/ household*
Daily household outdoor water use	*Calculation*	*76*	*159*	*100*	*92*	*gal/day/ household*
Daily household irrigation water use (outdoor water use excluding pools)	***Calculation***	***67***	***134***	***78***	***83***	***gal/day/ household***
Option 2 Literature Review						
Daily household outdoor water use	Various	-	212[w]	145[y]	158[ʁ]	gal/day/ household
Daily household irrigation water use (outdoor water use excluding pools)	***Calculation***	**-**	***179***	***113***	***143***	***gal/day/ household***

[*] Vickers (2001) for national data, [**] DeOreo *et al.* (2011), [†] calculated from Friedman *et al.* (2013), Romero & Dukes (2013), and Aquacraft (2014), [‡] calculated from Hermitte & Mace (2012) and National Wildlife Federation & Sierra Club (2010). [w] calculated from NRDC & Pacific Institute (2014), [y] calculated from Romero & Dukes (2013) and [ʁ] obtained from Cabrera *et al.* (2013).

For purposes of reporting accomplishments and numbers associated with the WaterSense program, EPA typically uses Option 1.2.

Values for years other than 2010 were scaled from the ratio of 2010 literature review estimates to a Residential End Uses of Water (REUWS) study (AWWARF 1999) equation estimate. The equation used for calculating EUWC follows, with the data inputs described in Table 7.

$$EUWC = 0.046 * MPW^{-0.887} \times HSQFT^{0.634} \times LOTSIZE^{0.237} \times e^{1.116(SPRINKLER)+1.039(POOL)}$$

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.

Table 7 Inputs for EUWC Equation

Variable	Description	Data Source	Details
MPW	Marginal price of water	Raftelis/ AWWA	The calculation for marginal price of water is taken from Fisher, *et al.* 2005. The MPW are calculated based on Raftelis survey data (2000–2014) at the state, census region[4], and national level. See section 3.2.1 for appropriate choice of state or regional data.
HSQFT	Average home square footage	AHS	For national new construction and stock values: AHS (odd years 1985-2013). For state stock values: AHS by Census region[5] (odd years 1985–2013). For state new construction values: RECS by Census region (RECS years 1993–2009).
LOTSIZE	Size of lot	AHS	For national new construction and stock values: AHS (odd years 1985-2013). For state stock values: AHS by Census region (odd years 1985–2013). For state new construction values: Census Characteristics of New Housing by census region (available for 1976–2014).
SPRINKLER	Fraction of customers with in-ground sprinklers	RECS 2005	Fraction of homes by vintage with automatic watering systems; post-2005 fraction of new construction is held constant at the average of 2003–2005 fraction; post-2005 fraction of stock is scaled linearly between 2005 value and assumed 2030 value based on an average of 50 years of new construction values. Available nationally and for each of the 3 states.
POOL	Fraction of customers with swimming pools	N/A	By setting the value for pools equal to zero, EUWC represents irrigation water consumption rather than outdoor water consumption.

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 section 2.2.4.). In order to determine annual water savings 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 percent more water than those without timers (AWWARF 1999).

<u>Percent Savings</u>

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

[4] NORTHEAST REGION: Connecticut, Maine, Massachusetts, New Jersey, New Hampshire, New York, Pennsylvania, Rhode Island, Vermont
MIDWEST REGION: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
SOUTH REGION: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia
WEST REGION: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

[5] The data are sufficient only for a regional disaggregation.

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 with the inputs described in Table 8. 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.

Table 8 Data Inputs for Market Share by Controller Type

Variable	**Data Source**
Total Shipments	EPA for 2012–current year, with scaling in other years (see section 2.2.1). For state level data, EPA national data were scaled by either the proportion of state level number of new building permits multiplied by penetration of sprinklers or the number of landscaping service employees compared to the national level; for other years, the shipments are extrapolated by adopting a trend established by the national growth rate of number of landscaping service employees, or by the state growth rate of number of new building permits (see section 2.2.1).
WBIC Shipments	*Policy Case 2011–2019*: Transparency Market Research. For state level data, one of the two scale factors is selected. *Policy Case 2020–2030*: Same trend as total shipments. *Base Case 2011–2014*: The difference between Transparency Market Research values and EPA sales values for WaterSense-labeled shipments. For state level data, both of these values are scaled. *Base Case 2015–2030*: Same trend as total shipments
SMS Shipments	*Policy/Base Case 2012–2014*: EPA data. For state level, this is scaled. *Policy/Base Case 2014–2030*: Holding constant at average percentage share across 2012–2014.
Timer Shipments	The portion of the market that is not WBIC or SMS.

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, annual water savings 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.

2.2.4 National Annual Water Savings

National annual water savings is the product of the annual water savings 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 annual water savings 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.

$$AWC\_frz_y = Households \times EUWC_y \times Days/Year$$

$$AWC\_base_y = AWC\_frz_y - \sum (stock_v \times UWS\_base_v) = AWC\_frz_y - AWS\_base_y$$

$$AWC\_WS_y = AWC\_base_y - \sum (stock_v \times UWS\_WS_v) = AWC\_base_y - AWS\_WS_y$$

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).

3 NET PRESENT VALUE

LBNL calculates the NPV of the reduced water costs associated with the difference in water savings between the policy case and the base case.

3.1 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).

We are currently not accounting for the costs of purchasing and installing any product. Additional data would enable those costs to be added in future versions of the model.

LBNL determined the PVS according to:

$$PVS = \sum WCS_y \times DF_y$$

Where:

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

LBNL calculated the total annual savings in operating costs by multiplying the number, or stock, of the product (by vintage) by its per-unit water cost savings (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.

LBNL determined the *PVS* for each year from the initiation of the WaterSense labeling program until 2030. LBNL calculated savings as the difference between the policy case and the base case.

LBNL calculated a discount factor 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.

3.2 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.

3.2.1 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. LBNL assumes that products 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 section 2.2.2.

3.2.2 Annual Water and Wastewater Cost Savings per Unit

LBNL 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.

Equations for estimating the per-unit annual water consumption for the base case and the policy case were presented in section 2.2.4. To determine the monetary value of the gallons of water saved by the labeling program, LBNL used 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 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). We followed three steps in calculating average prices per unit volume.

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.

Table 9 Average Prices for Water and Wastewater for the Residential Sector

Census Region	Weight	2014 Price ($/1,000 gallons) (2014$)	
		Water	Wastewater
Midwest	0.214	4.26	5.52
Northeast	0.170	4.51	5.89
South	0.380	4.24	6.05
West	0.236	5.06	4.76
National	1.000	4.49	5.61

To estimate the future trend for water and wastewater prices, we used data on the historic trend in the national water price index (U.S. city average) from 1970 to 2015 from the Bureau of Labor Statistics Water and Sewerage consumer price index (BLS 2015). We extrapolated the future trend based on the linear growth from 1970 to 2015 and used the extrapolated trend to forecast prices through 2030.

3.2.3 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 section 3.1.

3.2.4 Discount Factor

LBNL multiplied monetary values in future years by a discount factor to determine their present values. The discount factor (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. LBNL recommends using a three-percent and a seven-percent real discount rate, 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*. LBNL defined the present year as 2015.

3.2.5 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 represent decreases in water costs associated with more products purchased under the policy case compared to the base case.

4 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 report describes the novel approach LBNL developed to estimate impacts of the U.S. EPA's WaterSense labeling program for both indoor and outdoor water-consuming products. LBNL's models quantify the water savings and associated NPV attributable to the program. It enables users to assess the product-specific and aggregate impacts of the WaterSense program on water consumption and related costs across the U.S. It is worth noting that future data, including shipments and water price, can easily be incorporated into the model to provide up-to-date water savings estimations. This allows for continued tracking of the WaterSense program's impact on the market over time and provides valuable feedback to the EPA, industry partners, and other stakeholders on the efficacy of the program.

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