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Methodology for Outdoor Water Savings Model and Spreadsheet Tool for U.S. and Selected States

Alison Williams, Yuting Chen, Camilla Dunham, Heidi Fuchs, Sarah Price, and Hannah Stratton

Energy Technologies Area
Lawrence Berkeley National Laboratory
Berkeley, California USA 94720

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Green lawns and landscaping are archetypical of the populated American landscape, and typically require irrigation, which corresponds to a significant fraction of residential, commercial, and institutional water use. In North American cities, the estimated portion of residential water used for outdoor purposes ranges from 22-38% in cooler climates up to 59-67% in dry and hot environments, while turfgrass coverage within the United States spans 11.1-20.2 million hectares (Milesi et al. 2009). One national estimate uses satellite and aerial photography data to develop a relationship between impervious surface and lawn surface area, yielding a conservative estimate of 16.4 (± 3.6) million hectares of lawn surface area in the United States—an area three times larger than that devoted to any irrigated crop (Milesi et al. 2005). One approach that holds promise for cutting unnecessary outdoor water use is the increased deployment of "smart" irrigation controllers to increase the water efficiency of irrigation systems. This report describes the methodology and inputs employed in a mathematical model that quantifies the effects of the U.S. Environmental Protection Agency's WaterSense labeling program for one such type of controller, weather-based irrigation controllers (WBIC). This model builds off that described in "Methodology for National Water Savings Model and Spreadsheet Tool–Outdoor Water Use" and uses a two-tiered approach to quantify outdoor water savings attributable to the WaterSense program for WBIC, as well as net present value (NPV) of that savings. While the first iteration of the model assessed national impacts using averaged national values, this version begins by evaluating impacts in three key large states that make up a sizable portion of the irrigation market: California, Florida, and Texas. These states are considered to be the principal market of "smart" irrigation controllers that may result in the bulk of national savings. Modeled water savings and net present value for these three states should be more accurate and representative than the averaged national values given state-specific inputs such as lot size, water price, and housing stock. To complete the picture of national impacts, the remaining WBIC shipments not assigned to these three states are assessed using the original methodology based on the averaged national values.

1 INTRODUCTION

This report describes the method Lawrence Berkeley National Laboratory (LBNL) developed to estimate impacts of the U.S. Environmental Protection Agency's (EPA's) WaterSense labeling program for weather-based irrigation controllers (WBIC). This model was originally described in "Methodology for National Water Savings Model and Spreadsheet Tool–Outdoor Water Use" and analyzed impact using national average estimates. In this version of the model, we assess national impacts by analyzing state-specific inputs for three states representing a large share of the irrigation market—California, Florida, and Texas—and analyzing national average inputs for the remainder of the market. Estimated impacts include the water savings attributable to the program and the net present value (NPV) of the lifetime water savings from more efficient irrigation controllers. Although the WaterSense–Outdoor program currently focuses on WBIC, tracked shipments of other types of irrigation controllers could potentially be included in the model in the future. This report focuses on WBIC.

LBNL developed a mathematical model to quantify the water and monetary savings attributable to the WaterSense labeling program for outdoor products. The Water Savings–Outdoor (WS–O) model is a spreadsheet tool with which the EPA can evaluate the success of its program for encouraging buyers to purchase more efficient irrigation products. WaterSense initiated its program for outdoor products by focusing on WBIC. EPA places its WaterSense label on WBIC products that meet a set of technical specifications. WBIC have been shown in a number of field studies to save water compared to conventional clock timer controllers. The WS–O model forecasts the amount of water that will be consumed by irrigation systems that do and do not use WaterSense-labeled controllers. In developing inputs to the model, LBNL consulted numerous sources, including those described in Dunham *et al.* 2009, Melody *et al.* 2014, and Williams *et al.* 2014. The sources used to develop the final model values are also noted in this report.

This paper explains the data LBNL collected and the calculations it used to estimate the water savings associated with WaterSense-labeled WBIC. The calculation of water savings relies on three values: (1) the number of irrigation controllers in use; (2) the market share of irrigation controllers by type (i.e., timers, WBIC, and soil moisture sensors); and (3) the water saved annually for WBIC units compared to timers, or unit water savings (UWS). LBNL derived the number of units in use by applying an accounting method to product shipments and product lifetimes. The market share by type depends on base case and policy case projections of WBIC penetration. The UWS is based on the annual end-use water consumption for homes with automatic irrigation systems, and the percentage of water the WBIC irrigation device saves. To quantify the monetary value of the water savings attributable to the WaterSense–Outdoor program, LBNL also developed prices and price trends for water and wastewater services.

In developing the 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.

Section 2 of this report summarizes the WS–O model 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 water and wastewater prices and price trends.

2 NATIONAL WATER SAVINGS

LBNL calculates both annual national water savings (NWS) and cumulative NWS throughout the period of interest, which extends from initiation of the WaterSense program for WBIC (2012) to 2030.[1] Positive values of NWS represent water savings, meaning national water use under the WaterSense program and assumes that use is lower than in the base case.

For the NWS estimation, LBNL provides two options:

- National Only: NWS obtained with the national average inputs; and
- NWS obtained as the sum of water savings from California, Florida and Texas, which are calculated based on state-specific inputs, and the rest of US which is estimated based on national average inputs.

The difference between the obtained NWS illustrates the heterogeneous character of water saving resulted from the WaterSense program for WBIC, which is why the state-level analysis is included and meant to yield a more accurate NWS estimation.

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.

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 (2012 to 2030). This calculation is represented by the following equation.

$$NWS_{cumulative} = \sum_{i=2012}^{2030} NWS_y$$

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[1] The program began in late 2011, but no shipments are assumed that year.

2.2 Inputs to the Calculation

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 irrigation controllers include both shipments to new residential construction and shipments to existing homes. Although the WaterSense–Outdoor program currently focuses on WBIC, tracked shipments of irrigation controllers also include timers and soil moisture sensors (SMS) to aid in understanding market impacts as well as to potentially include SMS in future updates to the model.

$$Shipments = ShipNC + ShipExist$$

Where:

$Shipments$ = total shipments of irrigation controllers (timers, WBIC, and SMS);
$ShipNC$ = shipments to new construction; and
$ShipExist$ = shipments to existing homes.

Total shipments of irrigation controllers are based on EPA data for 2012 through 2015. For state-level data, the national shipments are scaled by one of five scale factors:

- the state-specific number of landscaping service employees compared to the national value[2];
- the state-specific number of new building permits[3] compared to the national value;
- the number of new homes (built after 2000) with irrigation controllers in each of the three states[4] compared to the national value;

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[2] Data obtained from the U.S. Census Bureau's Economic Census of 2002, 2007, and 2012 for North American Industry Classification System (NAICS) code 56173. Although that NAICS code encompasses employees beyond irrigation installers, no greater specificity was available. The U.S. Census Bureau defines the landscaping industry as "(1) establishments primarily engaged in providing landscape care and maintenance services and/or installing trees, shrubs, plants, lawns, or gardens and (2) establishments primarily engaged in providing these services along with the design of landscape plans and/or the construction (i.e., installation) of walkways, retaining walls, decks, fences, ponds, and similar structures."

[3] Data obtained from the U.S. Census Bureau's Building Permits Survey for 1960–2014.

[4] Data obtained from the U.S. Energy Information Administration's RECS 2005.

- the number of all homes with irrigation controllers in each of the three states compared to the national value[4], or
- the number of new buildings in each of the three states[3] multiplied by the state-specific penetration of irrigation controllers[4].

The shipments to the remainder of the nation are then the total shipments minus the number of state level shipments.

For years before 2012 and after 2015, national and state-level shipments trends were developed separately given the data limitations on which the scale factors are derived. The following are the corresponding three growth rate options for both the national level and the state level:

- the average growth rate based on annual number of paid employees in landscaping companies (Census 1998–2013);
- the average annual new building permits growth rate; or
- the average annual growth rate based on the number of new building permits multiplied by the penetration of irrigation controllers.

Note that the last option is adopted when one of three scalars is selected as the state shipments scalar (the proportion of new homes with irrigation controllers, the proportion of all homes with irrigation controllers, or the new building permits with penetration of irrigation controllers) since the controller installed rate in new homes should capture more accurately the growth of this market.

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 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 2010–2014 housing stock data are provided by American Community Survey (ACS) 5-Year Estimates, the trend of which 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 Energy Information Administration's Residential Energy Consumption Survey (RECS). We accessed the most recent data for this information, derived from the 2005 RECS.[5]

$$ShipNC = NewHomes \times Sprinkler$$

Where:

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

More detailed shipments data than what are available could divide the shipments to existing homes into two values: (1) shipments to replace failed controllers, and (2) shipments for new installations. However, efforts to date have produced insufficient data on WBIC lifetimes and markets to be able to build a shipments model by those two market types. Consequently, 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 irrigation controllers for any given year represents the sum of all the stock of stipulated vintages that continue to function. Stock also can be expressed as the product of shipments of given vintages and the percentage survival for each vintage.

$$Stock_{y,(n,c,f,t,or\ r)} = \sum Stock_v$$

$$Stock_{y,(n,c,f,t,or\ r)} = \sum (Shipments_v x\ Surv_v)$$

Where:

$Stock_v$ = stock of a given vintage surviving in a given year,

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[5] 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.

$Stock_y$ = stock of all vintages surviving in a given year,
$Surv_v$ = percentage of units of a given vintage surviving in a given year,
y = year,
n = nation,
c = California,
f = Florida,
t = Texas, and
r = nation excluding California, Florida, and Texas.

We developed the inputs to the survival function of units based on a variety of sources listed in Table 1. Approximately half of the WBIC market is expected to have site-based sensors that may fail sooner than the controller itself. 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. 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 1 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

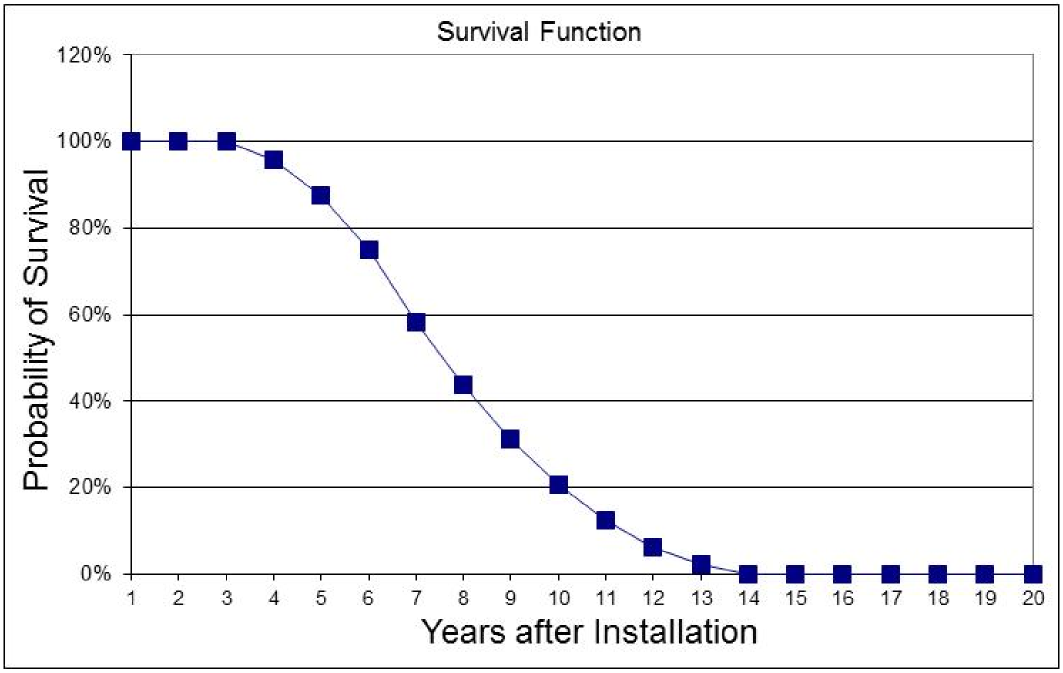

Figure 1 Probability of Survival of WBIC

2.2.3 Annual Water Savings per Unit

The annual water savings per unit (UWS) expresses the volume of water associated with a given end use that is saved by a more efficient device during one year. UWS is calculated as the product of water use for a specific end use (in this case irrigation) multiplied by the percentage of water savings. It is assumed that only one controller serves each household; hence the end-use water consumption is equivalent to the per-unit consumption. UWS is calculated separately for the policy case and the base case.

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

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.

End-Use Water Consumption

We initially determined a value for the end-use water consumption (EUWC) of outdoor irrigation water use for 2010, as described in Table 2.

Table 2 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 option 1, the estimated irrigation water use was for 2010, therefore values for years other than 2010 were scaled from the 2010 values using the ratio of the estimates shown in Table 2 provided by the model developed in the Residential End Uses of Water (REUWS) study

(AWWARF 1999).[6] For option 2, the estimated irrigation water use value was based on a literature review with most survey years around 2005; therefore, values for years other than 2005 were scaled from the ratio of 2005 literature review estimates to the REUWS equation estimate. The equation provided for calculating EUWC follows, with the data inputs described in Table 3.

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

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.

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[6] It should be noted that the Research Foundation is updating the residential end use water consumption estimates but the data and report are not yet publically available.

Table 3 Inputs for EUWC Equation

Variable	Data Source	Details
MPW	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[7], and national level. See section 3.2.1 for appropriate choice of state or regional data.
HSQFT	AHS	For national new construction and stock values: AHS (odd years 1985-2013). For state stock values: AHS by Census region[8] (odd years 1985–2013). For state new construction values: RECS by Census region (RECS years 1993–2009).
LOTSIZE	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	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	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).

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[7] 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

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

This calculation is described in the equations below and in Table 4.

$$EUWC = EUWC\_nocont \times (1 - SPRINKLER) + EUWC\_cont \times SPRINKLER$$

$$EUWC\_cont = 1.47 \times EUWC\_nocont$$

$$EUWC\_cont = \frac{EUWC}{\frac{(1 - SPRINKLER)}{1.47} + SPRINKLER}$$

Where:

EUWC_nocont = end-use (*i.e.*, irrigation) water consumption for households without irrigation timers in gallons per household per day.

Table 4 End-Use Water Consumption for Irrigation Controllers - Stock (2010)

Parameter	Source	National	CA	FL	TX	Units
Option 1.1 Estimation (Number of Households from AEO and U.S. Census Bureau)						
Daily household irrigation water use (outdoor water use excluding pools)	*Calculation*	68	121	62	73	*gal/day/ household*
Percent homes with sprinklers	Assumption based on RECS 2005 data	21	55	46	28	percent
Increased water use in homes with irrigation timers*	AWWARF 1999	47				percent
Daily household irrigation water use in homes with irrigation controllers	*Calculation*	91	141	75	95	*gal/day/ household*
Option 1.2 Estimation (Numbers of Households from RECS 2009)						
Daily household irrigation water use (outdoor water use excluding pools)	*Calculation*	67	134	78	83	*gal/day/ household*
Daily household irrigation water use in homes with irrigation controllers	*Calculation*	90	157	94	108	*gal/day/ household*
Option 2 Literature review						
Daily household irrigation water use (outdoor water use excluding pools)	*Calculation*	-	179	113	143	*gal/day/ household*
Daily household irrigation water use in homes with irrigation controllers	*Calculation*	-	209	137	186	*gal/day/ household*

* Assumes that all sprinklers have timers, a conservative assumption for determining the basis for savings.

Percent Savings

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 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 5. 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 5 Data Inputs for Market Share by Controller Type

Variable	**Data Source**
Total Shipments	EPA for 2012–2014, 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) and summarized in Table 6. 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.

Table 6 Water Savings by Controller Type

Controller Type	Average Water Savings
Timers	0% (N/A)
WBIC	15%
SMS	38%

Source: Williams *et al.* 2014

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 irrigation controllers in use to evaluate water savings from the program. The model, however, does estimate annual water consumption for irrigation 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 (2010 penetration of WBIC and SMS),
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.

Similar to NWS calculation, LBNL also provides two options to estimate the national NPV in order to illustrate the heterogeneous nature of the market:

- the "National Only" option uses the national average inputs for the estimation;
- the second option calculates national NPV as the sum of NPV for three states (California, Florida and Texas) and the NPV calculated for the rest of US.

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 WBIC. 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 (2012) 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 (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 Annual Water and Wastewater 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 WS–O labeling program, LBNL used 2012 and 2014 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.

For state-level calculations, the LBNL model provides two options for assigning water prices in selected states: either the water price for the state (i.e., excluding step 3 above) or for the state's Census region (West for California, South for Florida and Texas). Regional prices are associated with a larger sample size, as shown in Table 7; however, it is questionable whether the regional value accurately describes the state-specific prices. The best choice depends on the comparison of price variation inside the region and the price variation inside the state. If the price is homogeneous inside the state, then the small sample size would not influence the accuracy of the estimated price. Otherwise, it might be more appropriate to use the Census region prices. Table 8 shows the range, median, and standard deviation for the state and census region water prices collected in the Raftelis survey for 2014. Given the wider price variation in the Census regions, the state prices are more suitable to use.

Table 7 Number of Utilities Available for State-Specific Water Price Estimation

States and Regions Years	California	Florida	Texas	South	West
2000	9	9	14	72	40
2002	9	6	12	56	30
2004	23	19	18	97	69
2006	20	12	16	85	58
2008	16	6	12	57	39
2010	17	8	12	58	46
2012	35	19	23	123	77
2014	34	19	24	123	88

Table 8 Average Water Price Statistics by State and Region

State (n)	2014 Average Water Price ($/1000 gal)			
	Minimum	Maximum	Median	Standard Deviation
California (34)	2.35	10.19	6.38	1.65
Florida (19)	2.09	7.44	3.61	1.47
Texas (24)	2.56	8.31	4.24	1.21
Census Region – West (88)	1.70	11.91	4.67	1.81
Census Region – South (123)	1.96	11.04	4.00	1.60

Table 8 presents the results of the three-step calculation outlined above. The table includes the relative weight we assigned to each Census region when developing the nationwide average, as well as the prices for the three 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
State			
CA		5.70	4.05
FL		3.78	5.79
TX		4.42	4.96

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. Insufficient data were available to develop a different trend for each of the three states.

3.2.2 Equipment Stock

The stock of controllers in any given year depends on annual shipments and the lifetime of the controllers. The WS–O model tracks 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.

3.2.3 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:

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

Where:

r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

The WS–O model 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 (2012) to any given year through 2030. Savings represent decreases in water costs associated with more WBIC equipment purchased under the policy case compared to the base case.

4 CONCLUSION

This report describes the approach LBNL developed to estimate impacts of the U.S. EPA’s WaterSense labeling program for WBIC. By analyzing both national and state-specific inputs for three states, the water savings attributable to the program and the NPV of the lifetime water savings from more efficient irrigation controllers are evaluated and quantified. For the future iterations of the model, state-specific controller shipments data would increase the precision of the savings calculation and predictive capability of the model. 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 saving estimations.

5 BIBLIOGRAPHY

American Water Works Association Research Foundation (AWWARF). Prepared by P.W. Mayer and W.B. DeOreo for the AWWARF. 1999. Residential End Uses of Water (REUWS). Denver, CO..ISBN 1-58321-016-4. http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf.

Aquacraft. 2014. Some Key Results from REUWS2. Water Smart Innovations Conference, Las Vegas, NV, October 2014. http://www.aquacraft.com/wp-content/uploads/2015/09/Some-Key-Results-from-REUWS2_WBD-20141002.pptx.

Cabrera, R.I., K.L. Wagner, and B. Wherley. 2013. *"An Evaluation of Urban Landscape Water Use in Texas."* Texas Water Journal 4(2): 14-27. Texas Water Resources Institute. https://journals.tdl.org/twj/index.php/twj/article/view/6992

DeOreo, W.B., P.W. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, R. Davis, J. Henderson, B. Raucher, P. Gleick, and M. Heberger. 2011. *California Single-Family Water Use Efficiency Study*. Sponsored by California Department of Water Resources; managed by Irvine Ranch Water District. http://water.cityofdavis.org/Media/PublicWorks/Documents/PDF/PW/Water/Documents/California-Single-Family-Home-Water-Use-Efficiency-Study-20110420.pdf.

Dunham, C., J.D. Lutz, and M. Melody. 2009. Review of Literature for Inputs to the National Water Savings Model and Spreadsheet Tool–Commercial/Institutional. Lawrence Berkeley National Laboratory: Berkeley, CA. Report No. LBNL-2050E. https://escholarship.org/uc/item/6q64p315.

Fisher, D.C., C. Dunham, and M. Melody. 2006. National and Regional Water and Wastewater Rates For Use in Cost-Benefit Models and Evaluations of Water Efficiency Programs. Lawrence Berkeley National Laboratory: Berkeley, CA. https://escholarship.org/uc/item/0q0365tx.

Friedman, K., J.P. Heaney, M. Morales, and J.E. Palenchar. 2013. "*Predicting and Managing Residential Potable Irrigation Using Parcel-Level Databases.*" Journal – American Water Works Association 105(7): E372-E386. http://www.awwa.org/publications/journal-awwa/abstract/articleid/37538667.aspx

Hermitte, S.M.and R.E. Mace, 2012. The Grass is Always Greener … Outdoor Residential Water Use in Texas. Texas Water Development Board Technical Note 12-01. http://www.twdb.texas.gov/publications/reports/technical_notes/doc/SeasonalWaterUseReport-final.pdf.

Mayer, P., W. DeOreo, M. Hayden, R. Davis, E. Caldwell, T. Miller, and P.J. Bickel. 2009. Evaluation of California Weather-Based "Smart" Irrigation Controller Programs. California Department of Water Resources, Metropolitan Water District of Southern California, and East Bay Municipal Utility District: Oakland, CA.

http://www.cityofpaloalto.org/civicax/filebank/documents/18301.

Melody, M., H. Stratton, A. Williams, and C. Dunham. 2014. Resources for Outdoor Water Use Determination. Lawrence Berkeley National Laboratory: Berkeley, CA. Report No. LBNL-6672E. http://escholarship.org/uc/item/78r1j3dt.

Milesi, C., C.D. Elvidge, J.B. Dietz, B.T. Tuttle, R.R. Nemani, and S.W. Running. 2005. "A Strategy for Mapping and Modeling the Ecological Effects of U.S. Lawns." NASA Ames Research Center, Moffett Field, CA. http://www.isprs.org/proceedings/XXXVI/8-W27/milesi.pdf.

Milesi, C., C.D. Elvidge, and R.R. Nemani. 2009. Assessing the Extent of Urban Irrigated Areas in the United States. In *Remote Sensing of Global Croplands for Food Security*. P. Thenkabail, J.G. Lyon, H. Turral, and C. Biradar, Editors. CRC Press, Taylor & Francis Group: Boca Raton, FL.

Natural Resources Defense Council and Pacific Institute. 2014. *Urban Water Conservation and Efficiency Potential in California.* Issue Brief 14-05-D. http://pacinst.org/wp-content/uploads/sites/21/2014/06/ca-water-urban.pdf

National Wildlife Federation and Sierra Club. 2010. Sprayed Away: Seven Ways to Reduce Texas' Outdoor Water Use. Texas Living Waters Project: Austin, TX. http://texaslivingwaters.org/wp-content/uploads/2013/03/sprayed-away_report.pdf

Raftelis Financial Consultants/American Water Works Association. 2015. Water and Wastewater Rates Survey, 2014..

Romero, C.C. and M.D. Dukes. 2013. "Estimation and Analysis of Irrigation in Single-Family Homes in Central Florida." *Journal of Irrigation and Drainage Engineering* 140(2): 04013011. http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29IR.1943-4774.0000656

Transparency Market Research. 2014. Smart Water Management Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 – 2019. Transparency Market Research.

U.S. Census Bureau. 1998–2013. County Business Patterns (NAICS), Item: NAICS Code 56173, Landscaping Services. U.S. Department of Commerce: Washington, DC. http://www.census.gov/econ/cbp/.

U.S. Census Bureau. 2010–2014. American Community Survey. U.S. Department of Commerce: Washington, DC. http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_14_5YR_DP04&src=pt.

U.S. Census Bureau; U.S. Department of Housing and Urban Development. 2014. Characteristics of New Housing. U.S. Department of Commerce: Washington, DC. https://www.census.gov/construction/chars/highlights.html.

U.S. Census Bureau. 2013. American Housing Survey. Sponsored by the U.S. Department of Housing and Urban Development. U.S. Department of Commerce: Washington, DC. http://www.census.gov/programs-surveys/ahs.html.

U.S. Census Bureau. Building Permits Survey, Annual History by State, 1960–2014. U.S. Department of Commerce: Washington, DC. https://www.census.gov/construction/bps/pdf/annualhistorybystate.pdf.

U.S. Census Bureau, Housing and Household Economic Statistics Division. Historical Census of Housing Tables. Last Updated October 31, 2011. U.S. Department of Commerce: Washington, DC. https://www.census.gov/hhes/www/housing/census/historic/units.html.

U.S. Bureau of Labor Statistics. 2014. Consumer Price Indexes, Item: Water and Sewerage Maintenance, Series ID: CUUR0000SEHG01, U.S. City Average (not seasonally adjusted). U.S. Department of Labor: Washington, DC. http://www.bls.gov/cpi/home.htm#data.

U.S. Energy Information Administration (EIA). 2014. Annual Energy Outlook (AEO) 2014. U.S. Department of Energy: Washington, DC. EIA. http://www.eia.gov/forecasts/archive/aeo14/.

U.S. Energy Information Administration (EIA). 2005. Residential Energy Consumption Survey (RECS). U.S. Department of Energy: Washington, DC. http://www.eia.gov/consumption/residential/data/2005/.

U.S. Geological Survey (USGS). 2014. Estimated Use of Water in the United States in 2010. U.S. Department of the Interior: Reston, VA. http://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf

U.S. Office of Management and Budget (OMB). 2003. Circular A-4: Regulatory Analysis. http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf

Vickers, A. 2001. Handbook of Water Use and Conservation. Amherst (MA): Waterplow Press, p. 15-16.

Williams, A., H. Fuchs, and C. Dunham. 2014. Estimates of Savings Achievable from Irrigation Controllers. Lawrence Berkeley National Laboratory: Berkeley, CA. Report No. LBNL-6604E.

Williams, A., Y. Chen, C. Dunham, H. Fuchs, and H. Stratton. Methodology for National Water Savings Model and Spreadsheet Tool- Outdoor Water Use. Lawrence Berkeley National Laboratory: Berkeley, CA. Report No. LBNL-1004118