

Methodology for National Water Savings Model and Spreadsheet Tool—Outdoor Water Use

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METHODOLOGY FOR NATIONAL WATER SAVINGS MODEL AND SPREADSHEET TOOL—OUTDOOR WATER USE

1 INTRODUCTION

This report describes the method Lawrence Berkeley National Laboratory (LBNL) developed to estimate national impacts of the U.S. Environmental Protection Agency's (EPA's) WaterSense labeling program for weather-based irrigation controllers (WBIC). Estimated impacts include the national water savings attributable to the program and the net present value of the lifetime water savings for consumers of irrigation controllers.

LBNL developed a mathematical model to quantify the water and monetary savings attributable to the WaterSense labeling program for outdoor products. The National Water Savings–Outdoor (NWS–O) model is a spreadsheet tool with which the EPA can evaluate the success of its program for encouraging buyers to purchase more water-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. WBICs have been shown in a number of field studies to save water compared to conventional clock timer controllers. The NWS–O model forecasts the amount of water that will be consumed nationally by irrigation systems both with and without the WaterSense program. 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 for the final model values are also described in this report.

This report 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: the number of irrigation controllers in use, the market share of irrigation controllers by type (i.e., timers, WBIC, and soil moisture sensors (SMS)), and the water saved annually for WBIC units compared to timers, or unit water savings (UWS). LBNL derives the number of units in use by applying an accounting method to national 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 nationwide.

In developing the NWS–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 NWS-O, which are based solely on the residential market, are therefore likely to be a conservative estimate of savings.

Section 2 of this report summarizes the model and the inputs required for calculating the 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 consumption 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.

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.

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

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 focuses on WBIC, tracked shipments of irrigation controllers also include timers and soil moisture sensors (SMS).

$$Shipments = ShipNC + ShipExist$$

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 2014. For years before 2012 and after 2014, shipments were trended with county business pattern data on number of paid employees in landscaping companies (Census 1998-2013).

Shipments to new construction are calculated by multiplying the number of new homes by the percentage of new homes that have automatic sprinkler systems. We derived data on new homes in a given year from U.S. Census information contained in the biennial American Housing Survey (Census 2013). The percentage of those homes that have automatic irrigation systems 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.

$$ShipNC = NewHomes \times Sprinkler$$

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: shipments to replace failed controllers and shipments for new installations. Efforts to date have revealed data on WBIC lifetimes and markets to be insufficient to build a shipments model by market type, so 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.

$$Stock_y = \sum Stock_v$$

$$Stock_y = \sum (Shipments_v \times Surv_v)$$

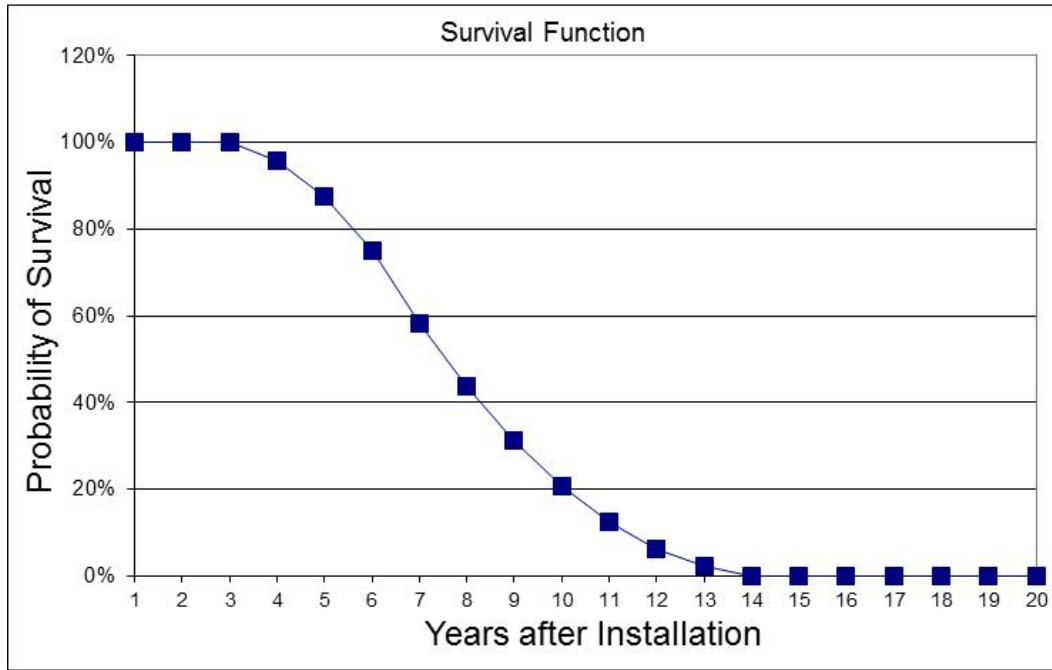
Where:

Stock_v = stock of a given vintage surviving in a given year,
Stock_y = stock of all vintages surviving in a given year, and
Surv_v = percentage of units of a given vintage surviving in a given year.

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	Value	Units
Public supply for domestic use + self-supplied withdrawals	USGS 2014 (Table 6)	27,400	million gallons (Mgal) per day
Number of households	AEO 2014	112.9	million homes
<i>Annual household water use</i>	<i>Calculation</i>	<i>243</i>	<i>gal/day/household</i>
Percent outdoor water use	Vickers 2001	31%	percent
<i>Annual household outdoor water use</i>	<i>Calculation</i>	<i>76</i>	<i>gal/day/household</i>
Percent homes with pools	RECS 2009	10%	percent
Increased water use in homes with pools	AWWARF 1999 (Table D.8 and Equation D.7)	123%	percent
Annual household irrigation water use (outdoor water use excluding pools)	Calculation	68	gal/day/household

Values for years besides 2010 were scaled from 2010 using the model developed in the Residential End Uses of Water (REUWS) study (AWWARF 1999). 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.

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
HSQFT	AHS	American Housing Survey collects housing data on a biennial basis.
LOTSIZE	AHS	
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.
POOL	N/A	By setting the value for pools equal to zero, EUWC becomes 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). 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	Value	Units
<i>Annual household irrigation water use (outdoor water use excluding pools)</i>	<i>Calculation</i>	68	<i>gal/day/household</i>
Percent homes with sprinklers	Assumption based on RECS 2005 data	21%	percent
Increased water use in homes with irrigation timers*	AWWARF 1999	47%	percent
Annual household irrigation water use in homes with irrigation controllers	Calculation	91	gal/day/household

* Assumes all homes with sprinklers have timers, which is a conservative assumption for determining the base 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)
WBIC Shipments	<i>Policy Case 2011-2019:</i> Transparency Market Research <i>Policy Case 2020-2030:</i> Same trend as total shipments <i>Base Case 2011-2014:</i> The difference between Transparency Market Research values and EPA sales values for WS-labeled shipments <i>Base Case 2015-2030:</i> Same trend as total shipments
SMS Shipments	<i>Policy/Base Case 2012-2014:</i> EPA data <i>Policy/Base Case 2014-2030:</i> 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 (with market penetration of WBIC and SMS essentially zero),

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

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

3 NET PRESENT VALUE

LBNL calculated the net present value (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 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 2.2.3. To determine the monetary value of the gallons of water saved by the NWS–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 supply pipe).

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 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 7 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.

Table 7 Average Prices for Water and Wastewater for the Residential Sector

Region	Weight	Price (\$/1,000 gallons) (2014\$)	
		Water	Wastewater
Midwest	0.214	4.26	5.52
Northeast	0.170	4.51	5.89
South	0.380	4.22	6.08
West	0.236	5.06	4.76
National	1.000	4.48	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 through 2014 from the Bureau of Labor Statistics Water and Sewerage consumer price index (BLS 2014). We extrapolated the future trend based on the linear growth from 1970 to 2014 and used the extrapolated trend to forecast prices through 2030.

3.2.2 *Equipment Stock*

The stock of controllers in any given year depends on annual shipments and the lifetime of the controllers. The NWS–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:

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

Where:

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

The NWS–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.

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