Invalid Substantiation for the EPA WaterSense® WBIC Program

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***Abstract*.** *There are 40.5 million acres of irrigated turf lawn in the United States making grass more widely irrigated that the eight following irrigated crops combined (Diep, 2011). The U.S. Environmental Protection Agency's (EPA's) WaterSense® program for weather-based irrigation controllers (WBIC) is designed to promote and enhance the market for commercial and residential irrigation controllers that create or modify irrigation schedules based on landscape attributes and real-time weather by labeling efficient irrigation system control technologies. The EPA anticipates, in full consideration of the research studies on weather-based controllers, realizing, on average, at least 15% saving of applied irrigation water after installation of weather-based irrigation controllers (EPA, 2009). This paper asks if the EPA can empirically and reliably infer from the data provided by the research studies cited by the EPA that WBICs save* $\geq 15\%$ *more water than traditional controllers for its nationally, targeted population. A meta-analysis of these studies shows evidence that the data cited by the EPA cannot be generalized for the purpose of providing a reference point for the EPA WaterSense® program and the assumptions of the EPA regarding the potential savings of WBICs are invalid.*

Keywords. weather-based irrigation controllers, EPA WaterSense, water saving assumptions of WBICs

Introduction

The rationale for the development of the WaterSense specification was determined by the assertion of the EPA and others that irrigation demand is the single largest end use of water in the urban sector in California and elsewhere (Mayer P. , DeOreo, Hayden, & Davis, 2009), forecasted to reach 58% by the year 2020 (Hunt, et al., 2001). Moreover, as much as half of this water is wasted due to evaporation, wind, or runoff often caused by improper irrigation system design, installation, maintenance or scheduling (EPA, 2011). The US Environmental Protection Agency's (EPA) WaterSense WBIC program is designed to address irrigation scheduling for residential and light commercial applications by labeling efficient irrigation system control technologies. Over a period of four years the EPA, in collaboration with irrigation controller manufacturers, water utilities, irrigation industry representatives, developed the *WaterSense Specification for Weather-Based Irrigation Controllers*, releasing the final iteration in 2011 (EPA, 2011). Irrigation controllers are to be tested in accordance with the Smart Water Application Technologies™ (SWAT) test protocols for climatologically based controllers utilizing climate data and some form of evapotranspiration data as a basis for scheduling irrigation. The SWAT protocol established the method by which controllers are tested and provides two output measures of performance: irrigation adequacy and irrigation excess. Irrigation adequacy is a measure of how well the plant's consumptive water needs are met and irrigation excess is a measure of water applied in excess of the plant's landscape consumptive needs (EPA, 2011). Required supplementary features are primarily utilitarian.

The foundation for the WBIC specification are the data derived from eleven research studies conducted from 2001-2009 on the efficacy and efficiency of weather-based controllers[1]. The EPA explicitly avers that, "in full consideration of the findings of these (eleven) numerous studies, WaterSense anticipates seeing overall water savings of approximately 15 percent after installation of weather-based irrigation controllers" (EPA, 2011). The EPA does not conduct its own testing or evaluations of weather-based controllers and relies on third party studies.

This study is a contribution to the discourse on water consumption in the urban sector in two linked areas: the need to conduct studies of urban water use using analysis of variance or other quantitative measures to account for variability and make predictions about water conservation devices, and, associated with the call for robust analysis, the need to empirically quantify consumptive use. It is the position of this paper that the effectiveness and efficiency of water conservation devices for landscape irrigation cannot be quantified without directly measuring outdoor water use. EPA WaterSense calculates detailed potential water, energy and cost savings from the performance of WBICs without empirical data to support its inferences. This paper posits that while the preponderant number of studies on WBICs explicitly examine the effectiveness and/or efficacy of weather-based controllers, the implicit objective of these publicly funded projects is to reduce irrigation water in specific service areas. This explains why the majority of projects target the highest water users and, ceteris paribus, why their results are not generalizable. Generalizability is applied by researchers in all quantitative academic settings. Simply put, generalizability is the extension of research findings and conclusions from a study conducted on a sample population to the population at large. The EPA WaterSense WBIC assumes that inference derived from the research studies are generalizable to the population of the United States who are 'candidates' for WBICs or, approximately, 12,825,000 households (EPA, 2009). What makes a study not generalizable for the entire population can be one or more parameters of the research design. In the case of the eleven research studies, the critical parameter that makes generalization not reasonable or probable is

[1] AquaConserve, 2002; Aquacraft, Inc., 2003; Carlos et al, 2001; Devitt, 2008; IRWD, 2001, LADWP, 2004; Mayer, 2009; MWDOC, 2004; Santa Barbara County Water District, 2003; Saving Water Partnership, 2003; University of Arizona, 2006

'selection bias'. Simply put, the samples selected subjects that are not representative of the target population.

Study Approach

The approach of this study is to conduct a meta-analysis of the research studies that serve as the foundation of the EPA WaterSense program with an emphasis on the generalizability of the studies. That is to say, can EPA WaterSense apply the results of the studies to the wider population it serves? The evidence of this analysis shows that the data are not reliable because water quantities were not measured and derived by extrapolative means and that non-probability sampling was used in virtually all studies. As will be shown, researchers engaged in 'judgmental sampling', deliberately selected their populations because of time or monetary limitations, in a minority of cases, or, in the majority of cases, because they were attempting to prove the efficacy of WBICs within a limited population. In no case, did the researchers randomly sample their populations and therefore, the results of their research cannot be used as generalizable to the entire population. This paper does not ascribe any normative values to the studies nor does this paper evaluate the individual studies. Similarly, this paper does not address the details of the specification of the WBICs nor does it address the performance or robustness of the controllers except for illustrative purposes.

The paper is organized as follows: the second section of the paper provides a short narrative summary of each of the studies examining them for reliability and generalizability. Following each narrative is a short review of the salient points for this study; the third part of the paper will present a table of the salient parameters of the studies; the fourth part of the study discusses the assumptions of EPA WaterSense and the calculations that were derived to justify the WaterSense program. The next section concludes that current data cannot serve to justify the WaterSense program for WBICs and recommends a different, more robust, research design that could lead to generalizable results.

The Research Studies

In the 2009 Appendix A of the WaterSense Draft Specification for Weather-Based Irrigation Controllers Supporting Statement the fourth assumption states that "large-scale, long-term studies have shown that on average, weather-based irrigation controllers have the potential to save at least 20 percent of applied irrigation water". (EPA, 2009). In 2011, the anticipation of EPA WaterSense was to estimate water savings of 15 percent, based on the same eleven studies and an additional study of California WBIC programs (Mayer, DeOreo, Hayden, & Davis, 2009).

AquaConserve (2002)

Residential landscape irrigation studies, using Aqua ET Controllers, were established with Denver Water in Denver, Colorado, and two adjacent water districts in Northern California, the City of Sonoma and the Valley of the Moon Water District, during 2001. The data collected from these studies indicated that participants had a total outdoor water savings of 21%, 23% and 28% for Denver Water, City of Sonoma and Valley of the Moon Water District , respectively (Addink & Rodda, 2002). The average water savings per participants in Denver was 21.47%; the average outdoor water savings per participant in Sonoma was 7.37%; and, the Valley of the Moon Water District average outdoor water savings per participants was 25.1%.
Aqua Conserve provided a list of high volume water users interested in the study project to the Sonoma County Water Agency and the Valley of the Moon Water District. Aqua Conserve personnel installed controllers at 27 residential sites in the City of Sonoma and at 10 residential sites in the Valley of the Moon Water District. All controllers were equipped with temperature sensors. Water usage during 2001 was compared to pre-installation historic use for previous two years for Sonoma and for previous five years for Valley of the Moon. If excessive wilting of the grass or brown spots began to appear in the lawns, the users could press a button and add an additional scheduled

watering (Addink & Rodda, 2002). There was substantial variation in the results, some participants had extremely high water savings, some no water savings and even a few had an increase in water usage compared to historic water usage. Some of the variability could be explained, for example, due to abnormally high water use when a participant added sprinklers, improper controller settings, etc. However, not all of the variability could be explained and rather than arbitrarily leaving out some data, the data from all the participants was included in the final result calculation.

While each study reveals significant savings it is important to point out that the manufacturer of the WBIC provided the agencies a list of high volume water users such that sampling of the population was not unbiased and the results, prima fascia, cannot be used to infer results in the general population Second, users were allowed to manipulate their controllers manually if they felt that additional water was necessary and, third, users were allowed to add sprinklers and increase their usage.

Aquacraft, Inc. (2003)

The Aquacraft, 2003, research study consists of ten controllers installed in Colorado of which nine were residential and one commercial. Seven of the participants volunteered for the study and three were selected based on their high water usage. Overall savings averaged about 20%, however, post-installation water usage increased at four of the sites which was explained by researchers as sites where volunteers had historically under-irrigated.

The results appear to be positive but are not generalizable because seven of the ten sites were voluntarily chosen and the remainder were selected because they were high water users. Volunteers for this study may be motivated by their preference for water conservation or to receive a free controller. Participants selected because of their high water use can only generate data that can be generalized for similar high water users.

Aquacraft (2009)

The Aquacraft, Inc. evaluation of California Weather-Based "Smart" controllers was designed to maximize potential water savings so the targeted sample selected for the Northern California portion of the study were historically high outdoor water users who were identified by historic billing data (Mayer, DeOreo, Hayden, & Davis, 2009). In Southern California, the target sample were 'interested and motivated customers' (Mayer, DeOreo, Hayden, & Davis, 2009). This study is quite broad and reflected the efforts of a collaborative group of agencies: California Department of Water Resources; California Urban Water Conservation Council; Metropolitan Water District of Southern California (MWD); the twenty-six member agencies of MWD in southern California; a consortium of six water agencies in northern California; and, the East Bay Municipal Utility District. There were 2,294 sites in this study, 3,112 controllers. There were three distribution methodologies used: rebate and vouchers; exchange programs; and, direct installations. This is a large study and it is helpful to display its data in table form:

It is important to display the three methods of distribution. The 'exchange' category refers to those users who disconnect their old controllers and bring them to a central location where they receive a WBIC. The 'rebate' program consisted of a check or voucher for a minimum of $50/controller. The 'direct install' were high water users solicited by the appropriate water agency.

Table 1: MWD Smart Controller Distribution by Member, Method and Customer Category (Mayer, DeOreo, Hayden, & Davis, 2009)

Agency	Residential			Commercial		Total
	Exchange	Rebate	Direct	Rebate	Direct	

			Install		Install	
Beverly Hills	1				41	42
Burbank	91					91
Calleguas	78			22		100
Central Basin	78			39	17	134
Eastern	3			100		103
Foothill	347	21				368
Glendale	168					168
Inland	286	93				379
Las Virgenes	22		1		45	68
Long Beach	47	32	198		67	344
LADWP	143		430		47	620
Pasadena	74		11	35		120
SDCWA	676	17		150		843
San Fernando	7					7
Santa Monica	61	3	63	2	1	130
Three Valleys	165					165
Torrance	20					20
USGV	167					167
West Basin	2	29			13	44
Western	39		207	52	379	677
TOTAL	2,475	195	910	400	654	4,634

The sample sets of each method of distribution was not random. Customers were either motivated volunteers, paid to switch out the controllers or solicited because they were high water users. It is not possible to generalize the savings based on the data. One can also observe that the water savings occurred for just above one-half the population.

Carlos (2001)

The Carlos experiment in Northern Nevada consists of four treatments: intuitive irrigation, manually ET scheduled irrigation, manually ET scheduled irrigation with management training, and ET satellite controlled irrigation. Preliminary results indicate a potential of 15-30% water savings using satellite technology. Estimates range from 50% to 70% of the total water supply is used for outdoor irrigation during the summer months and unpublished data suggests that in non-drought years residents typically apply anywhere from 2 to 10 times more water for landscape irrigation than is actually needed (Carlos, Miller, Devitt, & Fernandez, 2001). The study is a 4 x 2 factorial experiment with three replications in a completely random management design. The experiment utilizes localized data generated from weather stations to control the duration and frequency of outdoor irrigation. Weather station data are sent to a PC unit cellularly where ET_0 is computed then sent via satellite dish to an orbiting satellite. The satellite then beams the signal down to an irrigation controller individually located at the consumer's place of residence on a weekly basis. The controller opens the irrigation valve and automatically sets the duration and frequency of irrigation based on a preassessed application rate and distribution efficiency of the irrigation system. The 2001 study does not report any results.

The Carlos study is scientifically robust but two issues make its results inappropriate for generalizability to the EPA WaterSense program. First, the scope of the study is limited to the efficacy of satellite technology to manage landscape irrigation water and, second, while the experiment is conducted randomly, each experimental unit consists of similar turf variety and uniform cultural and management practices.

Devitt (2008)

The Devitt study is a mixed landscape experiment conducted on 27 residential sites in Las Vegas to quantify water savings associated with satellite irrigation controllers (Devitt, Carstensen, & Morris, 2008). A mixed landscape irrigation study conducted on 27 residential sites in Las Vegas to quantify water savings associated with satellite irrigation controllers (Devitt, Carstensen, & Morris, 2008). Seventeen sites were equipped with ET satellite irrigation controllers and ten sites were designated as control sites and retrofitted with non ET-based controllers. Results showed that 13 of the 16 ET Based controller sites saved water compared to four of ten of the non ET-based control sites. Statistical difference occurred between the control and ET based group (ET-based =+20% savings) ($p<0.05$)

Results from the study indicated that water savings were not because of deficit irrigations at the expense of the landscape plant material. Approximately 81% of the variation in the total outdoor use could be described by the total turfgrass area at each site. Such results would suggest that turfgrass limitations have merit, if the grass being restricted is tall fescue growing in an arid environment (Devitt, Carstensen, & Morris, 2008). Devitt, et al, assume that in communities such as Las Vegas, the highest percentage of wtaer use occurs in the residential sector (60%), with the majority used outdoors to irrigate lawns and mixed landscapes (70%). Sites were selected based on an extensive evaluation of landscape plant materials, irrigation system performance, homeowner level of interest in participating, and the presence of tall fescue in the front yard. Ten of the sites were designated as controls; five received seasonal irrigation scheduling information and five received no educational information. All received the identical irrigation controller. All homeowners in the control group were provided a two-page flier every three months on landscape water use and irrigation scheduling recommendations and tips. Electronic water meter-reading devices were installed on each residential water meter and irrigation was restricted to the hours between 10:00 PM and 5:00 AM. Water use (meter readings) at all residential sites, was compared with historical data for each site obtained from the local water purveyor. Indoor use was estimated by subtracting outdoor use (10 PM to 5 AM) from the total meter readings. Historical water use was for total water with no separation between indoor and outdoor use. The average water savings for all smart controller sites is reported to be approximately 20%, and individual savings ranged from 61.6% to -68.1% (US Department of the Interior, 2008).

The Devitt sudy was designed to examine the impact of WBICs in mixed landscape and concluded that the landscape plant material was not negatively effected by the ET-based controllers and 81% of the variation in the total outdoor water use could be described by the total turfgrass area at each site. The results, then, are generalizable in conditions where there is a preponderance of tall fescue turfgrass in an arid environment.

IRWD (2001)

The goal (of the research) of the Irvine ET Controller Study was to study as homogenous a group as possible to improve the validity of the findings. To that end, test sites were selected from "Westpark Village", a development located in the city of Irvine, California. Test homes were targeted as per traditional water conservation program guidelines, i.e., top 20% water users. For Westpark Village, residents with average annual consumption exceeding 200 Hundred Cubic Feet (HCF) derived from three years of billing data defined the top 20%. These 509 homes were sent letters requesting study volunteers. Over 130 households volunteered to participate. From these volunteers 40 homes were selected (Hunt, et al., 2001). Three household groups: a test group; a reference group to account for externalities; and, a postcard group (people receiving a postcard as weather changed suggesting the owners adjust their schedules) were selected. All treatment group households were surveyed prior to the retrofits to gauge their irrigation knowledge and practices and to gauge their receptivity and willingness to pay for this technology. Responses to these questions had no effect on determining whether the home was qualified to be in the study. Overall these results indicate both a genuine customer need as well as willingness to pay for convenient, reasonably priced, weather-based irrigation scheduling technologies and services. All test groups were selected from among the top 23% water users in the development. On an absolute basis, when savings were estimated through a statistical comparison of weather-normalized consumption before and after retrofit, WBICs were able to reduce total household water consumption by roughly 37 gallons per household per day, representing a 7% reduction in total household use or a projected 16% reduction in estimated outdoor use (Hunt, et al., 2001). The authors infer that by targeting roughly the top third of homes in terms of water use (approximately 10,000 homes) ET controllers might be expected to save roughly 57 gallons per household per day, a reduction of 10% in total water use or 24% in outdoor use.

The authors conclude that the total potential savings are suggested for illustration purposes only and that the study is not designed to generate widely generalizable inferences

LADWP (2004)

The LADWP weather-based irrigation pilot study was targeted at large multi-family residential (homeowner associations) and small commercial sites (parks, school, office buildings). The study was implemented during 2002 and 2003 (Bamezai, 2004). The authors posit that, to date, several studies have examined the effectiveness of weather-based irrigation controllers in single-family residential settings, but virtually none have systematically examined how these controllers perform in other types of settings with medium to large landscapes. All twenty-five sites in the study were professionally installed and programmed. On 60 of the 83 acres dedicated irrigation meters were installed. To avoid implementation delays, the study did not randomize the assignment of sites to the vendors. Test sites were selected on a first-come, first-served basis. LADWP staff identified potential commercial, industrial, institutional sites with significant landscapes by examining summer-winter usage differentials. They then contacted these sites to inform them about the pilot program, and to solicit participation. It was not an easy sell in spite of participants being insulated from all study expense. 25 sites were retrofitted with WBICs. Participants were steadily recruited and screened for suitability. At the time of selection, careful attention was paid to the general condition of the irrigation system. Sites with irrigation systems in significant disrepair or sites were significant alterations had been made to the landscape in the prior two years were excluded.

The LADWP site cannot be generalized for wider adoption because the sample set was not randomly selected.

MWDOC (2004)

In the summer of 2003, MWDOC was awarded a Proposition 13 non-point-source pollution control grant from the California State Water Resource Control Board to provide funding asistance for the installations of a new irrigation timer technology (Berg, Hedges, & Jakubowski, 2009). The study had two primary objectives: to capture pre- and post-Smart Time installation data for water quality and runoff flow for two neighborhoods; and, evaluate water savings on the same Smart Timers installed in the program. The "Orange County's Weather Based Irrigation Timer Rebate Reimbursement Program" examined water savings for the entire program area by single-family residences, water savings by commercial installations, runoff flow patterns during pre- and post-interventions, and water qualify changes resulting from WBIC installations. In addition, the study examined water savings by season, brand of Smart Time and type of installaer. The program wide savings of single family residences was about 0.7 Hundred Cubic Feet (HCF)/month (about 18.3 gallons/day (gpd) or 0.0045 gpd/sq ft of irrigated area. This estimate is arrived by calculating the total change in water use in cases where water use changed significantly (increased or decreased, $\alpha=0.05$) and averaging the net change by all the Smart Timers (899) that were qualified for evaluation. However, the amount of water saving will increase, according to the authors, to 1.4 HCF/month (35.7 gpd) if the estimates are made by averaging the net water change (significant increase or decrease) by only those Smart Timers (460) that contributed to significant change in water use (Berg, Hedges, & Jakubowski, 2009). Program wide savings in commercial settings averaged 7.6 HCF/month (about 190 gpd; 0.004 gpd/sq ft irrigated area). In 30% water consumption significantly decreased, 11% increased, 60% had no change. The authors identified three distinct trends in the single-family residences retrofitted with Smart Timers. In about 33% of the accounts, the water consumption significantly decreased ($\alpha=0.05$) after installation of Smart timers. In about 18% of the cases the water consumption increased statistically significantly after installation of Smart Timers. In nearly 50% of the accounts water use did not change significantly upon installation of Smart Timers. The selection process for the 500 single family residences in the study area consisted of a marketing campaign of directly-mailed postcards, letters and two weekend of direct door-to-door marketing by Boy and Eagle Scouts. Following the marketing campaigns, the fifty-three interested residents contacted the rebate program, purchased and installed an approved WBIC and then filed a rebate program application with MWDOC. Participation was a bit over 10% of the neighborhood (Kennedy/Jenks Consultants, 2008).

The authors advise that that this study, notwithstanding its extensive production of data, is limited because: the data were not normalized for weather with advanced statistical modeling; the results obtained were not compared to a control set of similar participants; and, the weather data used in the study was found to be inaccurate due to malfunctioning weather equipment such that all data are currently being re-run (Berg, Hedges, & Jakubowski, 2009). The recommendations of the authors for further study include; the need for periodic readjustment (of crop coefficients) due to seasonal changes; proportionate installation of WBICs in various ET zones; and, random population selection. They conclude that proactive early adopters of the WBIC technology do a better job overall of water conservation (Berg, Hedges, & Jakubowski, 2009).

Santa Barbara County Water District (2003)

The Santa Barbara County Water District program involved six agencies (Santa Barbara County Water Agency, City of Santa Barbara, Goleta Water District, City of Lompoc, City of Santa Maria, and, the Vandenberg Village Community Services District). Each agency developed a list of high-water using customers who served as the target audience for the ET Controller Program. Average water use for January and February and average use for July, August and September for the prior three years was determined for each customer. The average amount of landscaping at residential properties in the study area was about one acre and it was estimated that approximately 50 percent of the water used at a residence goes to the landscape. Then these averages were used to create a ratio of the difference between summer and winter to determine highest irrigation use. ET Controller Program brochures and letters from the water purveyor were mailed to the top 100 high water users from these lists for Goleta Water District and City of Santa Barbara and the top 25 for the other three agencies. (Litton, 2003). A marketing campaign and phone campaign to attract the highest users was conducted and participants had to pay $144 for a 3 year service plan up front. Site visits (6 hours per controller) for pre-screened customers were conducted by staff members which included a Customer To Do list which provided information on the required repairs and installer contact information. The WeatherTRAK ET Controller technology was chosen for the ET Controller Program because a study conducted by Irvine Ranch Water District it (sic) provided conclusive evidence that the WeatherTRAK controller supplied accurate irrigation scheduling by automatically creating a weekly irrigation schedule based on 'real time' evapotranspiration (ET) data from local weather stations (Litton, 2003). Preliminary data indicated that customers are reducing their monthly water use by approximately 26%, with a high of 59% savings and a low of 8% savings. The author further noted that using the factory settings for precipitation rates in the WeatherTRAK controller does not result in reliable savings. On average, the WBICs were over watering turf areas and under watered areas with drop systems.

This study is not generalizable because of sample selection, reliance on data from earlier, ungeneralizable studies and the absence of a reliable baseline.

Saving Water Partnership (2003)

The 2002 study was designed to test the savings potential and customer satisfaction of four types of irrigation controller devices: ET controller and sensor; wireless and hardwired rain sensor; ET controller without a rain sensor; and, irrigation scheduling service (Smith, 2003).
Participant selection was based on a customer's potential to save water. Participant selection was based on a customer's potential to save water. The study participants (including controls) used an average of 375 gallons per day during the peak season above their average daily winder use and are considered very high users. This list produced 2,000 names. Half were invited to participate and the other half would be used to select controls. The 20 participants who received the ET controller with a rain sensor realized the greatest water savings because these customers had a high savings potential. In the study area, the potential impact of utilizing the ET controller and sensor are 'great'. In Seattle there are about 315,000 single-family homes and approximately 15-20% have in-ground automatic irrigation systems. If the estimated 7875 customers who have the 44,800 differential and an automatic irrigation system, installed the ET controller with rain sensor, the Saving Water Partnership could potentially save 1.2 million gallons per day (Smith, 2003).

The above study is generalizable to areas with high water usage. There is evidence of a strong correlation between high water use differential and potential water savings. In these conditions a WBIC can be a valuable tool.

University of Arizona (2006)

This is a field study that evaluated water savings resulting from installation of weather and soil moisture based controllers. Data were collected at 27 residential sites in Tucson, Arizona during August 2004 to July 2006. Devices were installed by a landscape professional with support from manufacturer representatives. The participants consisted of volunteers and high water usage was not a selection criteria. Reported average water savings are 25% for the WBIC and 3.2% for a second WBIC and 4.3% for the moisture sensor WBIC. (US Department of the Interior, 2008).

The apparent success of this study can be traced to the selection of voluntary participants. This study contains a small sample size (27 homes) and does not cite independent third-party review as to the methodology uses and the soundness of the conclusions (Dukes, 2012)

Table of Summary of Case Studies

Table 2: Summary of Case Studies

Study	Customer Target	Marketing Strategy	Scope	Comments
AquaConserve (2002)	Manufacturer provided list of high volume water users	Direct, targeted approach whereby manufacturer directly contacts potential customers	37 WBICs	Users allowed to make adjustments
Aquacraft (2003)	7 volunteer subjects 3 selected as high water users	Initial phone calls and follow up if good candidate	10 WBICs	Reported savings of 20%
Aquacraft (2009)	High water users in half study Motivated customers in other half of study	Web, word of mouth, agency letter	2294 sites	Water savings for about one-half of sample
Carlos (2001)	Identical turf and uniform cultural and management practices of users	Unknown	Unknown but random within sample set	Satellite based technology
Devitt (2008)	Uniform landscape planting, presence of fescue, irrigation system, level of interest	Free controllers	27 WBICs	81% of variation due to preponderance of tall fescue grass
IRWD (2001)	Homogenous group: top 20% billing data identified	Letters requesting volunteers	40 WBICs	Authors cite ungeneralizability of study
LADWP (2004)	Large residential (HOAs), commercial, non-random, time constraints, first come-first-served	Solicited	25 WBICs	Installed meters on 60 of 83 acres
MWDOC (2004)	Intensive marketing campaign that, in the final analysis, required customers to contact the agency to participate	Marketing campaign, Boy Scouts, direct mailing, door-to-door campaign	1,222 WBICs	Less than half had significant water savings
Santa Barbara (2003)	Residential customers with highest water users	Letters to top 100 water users	62 WBICs	Customers had to pay $144 service fee
Saving Water Partnership (2003)	Residential customers with highest water use during peak season	Identified by water agency and directly contacted to participate	106 WBICs	About one-half water bills higher after first year

University of Arizona (2006)	Voluntary participants	Landscape professionals and manufacturers representatives identified users	27 WBICs	Tested WBICs of two types and moisture sensor

Assumptions and Calculations

The EPA WaterSense program derives a number of assumptions about the inferences that can be derived from the research studies. The assumptions are categorized under three headings: Potential water savings; Potential energy savings; and, Cost Effectiveness. The energy savings and cost effectiveness predictions rely on data generated from water savings data which are examined below.

1. The first assumption is that average outdoor usage is approximately 58,000 gallons of water annually. This data is based on Table 5.14 of the Residential End Uses of Water (Mayer, DeOreo, & al, 1999). However, the referred Table indicates an average outdoor use of about 84,738 gallons which represents 58% of total usage
2. The second assumption is that 13,500,000 detached single family homes have automatic irrigation systems based on EIA data
3. The third assumption is that 95% of irrigation systems are candidates for replacement. This is also derived from EIA data
4. The final assumption of the Potential Water Savings section identifies a 15 percent savings after installation of a WBIC.

The calculations that are derived from these assumptions are that each home can save 8,700 gallons/year. The correct assessment, based on the 15% assumption is a potential savings of 12,710 which equates to a potential annual water savings of 163 billion gallons of water per year and a net cost savings of almost $600 million per year

The purpose of this exercise is to illustrate the potential savings, and therefore the high value of conducting scientifically robust, valid, reliable and generalizable data.   The potential payoff, should empirical results be positively evaluated by third parties, is significant in terms of water, economic pay-off and energy conservation.

Conclusion

The overarching conclusion of this study is that the EPA WaterSense WBIC program requires robust and reliable data to justify the Weather-Based Irrigation labeling program. Evidence has shown that the data embedded in the studies upon which the foundation for the potential water savings is based are not generalizable. Each of the eleven studies that serve as reference points for the EPA WaterSense program do not provide data that can be generalized beyond the local scope of the individual study. The purpose of the research studies is to evaluate an effective device to reduce water consumption in the irrigation sector. The purpose of the studies is not to provide generalizable data that can be used on a national scale. This study is not a critical evaluation of the research studies. This paper stipulates that the data derived from the studies were used in an ex post facto manner by the WPA WaterSense WBIC program. The studies were not funded by the EPA nor were they designed to as generalizable studies for the national population.

Second, it is clear from the evidence that studies of water conservation do not employ metering devices for the purpose of quantifying irrigation consumption in the urban sector. This paper posits that the importance of water conservation, quantified by the potential savings in water, energy and dollars makes it critically important to measure the water we use for each sector. A quantitative study must be reliable, internally and externally valid, parsimonious, important, replicable and generalizable. Nothing else should be acceptable.

The EPA WaterSense WBIC program needs robust and formal studies to determine the effectiveness of weather-based controllers and should re-visit the issue of data reliability and generalizability when promoting the current program.

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