Valley Water

Water savings from turf removal and irrigation equipment rebates

Neeta Bijoor, PhD

Water savings from turf removal and irrigation equipment rebates

Author

Neeta Bijoor, Ph.D.

Water Conservation Specialist, Valley Water

Abstract

The State of California and several local and regional water agencies offer rebate programs for removing turf and replacing it with low-water use landscapes, and/or rebate programs for replacing conventional irrigation equipment with high-efficiency irrigation equipment. Confirming and quantifying program water savings would enable agencies to more thoroughly assess the benefit provided by these programs. A study was conducted at the Santa Clara Valley Water District (SCVWD) to determine the water savings associated with turf removal and irrigation equipment rebates offered through its Landscape Rebate Program (LRP). The study focused on single-family residences, which comprise the largest LRP participant type. Water use billing data for LRP participants was obtained from 10 retailers within the SCVWD service area. Water use up to three years prior to installation of a new landscape or irrigation equipment was compared to water use after installation, for a period up to five years. The following rebate types were studied: (1) conversion of turf area to a landscape of low-water use species in conjunction with drip irrigation (LND), (2) conversion of timer-based automatic irrigation controller to weather based irrigation controller with a rain shut-off device (WBIC+RN), (3) conversion of conventional nozzles to high-efficiency nozzles (HEN), and (4) conversion of conventional nozzles and sprinkler bodies to high efficiency nozzles and spray bodies with pressure regulation and/or check valves (HEN+BOD). LND savings were marginally significant the first year following conversion, and statistically significant for each study year afterwards. LND average water savings incrementally increased each year following conversion. Annual average LND savings were on average 31 gallons per square foot per year ($g/ft^2/y$) for years 2 to 5 when savings were significant, and were 48 $g/ft^2/y$ during the fifth year following conversion. The annual water savings for WBIC+RN were statistically significant each year following conversion, incrementally increased each year following conversion, and were on average 9 $g/ft^2/y$. The annual water savings for HEN were marginally significant in the first year, significant in the following two years, and were 1,243 g/unit/y on average. Annual savings for HEN+BOD were significant in the first year following conversion, and were 1,661 g/unit/y on average. This study shows that turf removal and irrigation equipment rebate programs can be successful in achieving water conservation goals, and describes factors that may contribute to program success.

Introduction

California experienced the most severe drought in the past 1,200 years from 2012-2014 (Griffin and Anchukaitis, 2014), and this drought continued until 2016. California's water storage and distribution systems are critically dependent on the Sierra Nevada snowpack, which is projected to decline by 64 percent by the end of this century (Reich et al., 2018). The snowpack reached a startling 5 percent of normal on April 1, 2015. In response, Governor Brown issued an executive order for the first ever statewide mandatory water use reductions, along with other measures to reduce water use (Executive Order No. B-29-15, 2015). Among the other measures was a requirement to replace 50 million square feet of turf with drought-tolerant landscapes to reduce water use in the urban sector. The State of California and local and regional water agencies implemented this plan through rebate programs to incentivize property owners to replace turf, and spent over $350 million on these rebate programs during the last two years of drought (Knickmeyer, 2016). As these programs were carried out by various agencies, they varied in implementation. However, all programs essentially shared the same requirement regarding the removal of turf, and typically offered between $0.50 - $4/square foot for its removal.

There is a critical need to quantify the benefit of conservation savings provided by these programs, relative to the cost. This will assess the effectiveness of these strategies to allow for science-based planning and guidance for future programs. While removal of turf, a water-intensive plant, might seem to obviously result in substantial water savings, this may not necessarily occur if irrigation practices are not changed concurrently. Though irrigation demand may decrease following turf removal, property owners may not reduce irrigation rates, either due to lack of awareness on the need to change irrigation practices, lack of knowledge regarding irrigation controllers or systems, or lack of willingness to change behaviors. Most programs have enforcement in place to ensure adherence to program requirements, for example, a post-inspection to ensure that turf has been removed and that replacement requirements have been met. However, property owners could evade program requirements following the post-inspection period (e.g. by planting high water use species). In addition, it is unknown how many years it would take for water savings related to turf removal to be realized, as replacement species may require substantial irrigation in the early years to establish.

Studies of the water savings associated with turf removal are impeded by lack of sufficient years of post-conversion data, the difficulty of obtaining water billing data, which may originate at several agencies, and the challenge of mining voluminous water billing data to analyze water savings and inform program management.

The Santa Clara Valley Water District (SCVWD), a wholesale water supply and groundwater management agency in Santa Clara County, CA, is in a unique position to conduct this study, as it has had a long-standing turf removal rebate program since 2007. The current version of the program has operated since 2010, allowing for the unique opportunity to examine the long-term water savings associated with the program. Data for this research study was obtained from 10 retailers through a voluntary research partnership with SCVWD. Examination of SCVWD's program also offers the opportunity to quantify savings from irrigation equipment rebates, as its program also offers rebates for weather-based irrigation controllers installed in conjunction with rain shut-off devices, high-efficiency nozzles, and sprinkler bodies.

This study focuses on evaluating the turf replacement and irrigation equipment rebate program offered by the SCVWD, also known as the Landscape Rebate Program (LRP). In this study, the water savings associated with the various elements of the LRP are assessed - the replacement of turf with low-water use species, automatic timer-based controllers with weather-based irrigation controllers, and conventional sprinkler nozzles with high-efficiency nozzles, both independently and in conjunction with sprinkler bodies.

Methods

Description of Study System

The SCVWD service area covers nearly 3,400 km^2 (1,300 mi^2) and includes 15 cities within Santa Clara County, comprising one of the state's largest urban centers (Silicon Valley). SCVWD provides water to 13 major retailers. The SCVWD service area experiences a Mediterranean climate with seasonal winter rainfall, and has a reference evapotranspiration of approximately 49 inches per year (California Irrigation Management Information System, www.cimis.water.ca.gov). During the period of this study, 2010-2016, the region experienced drought conditions during the periods from 2006-2010 and 2012-2016.

The SCVWD Landscape Rebate Program

The SCVWD LRP offers four rebate types which were analyzed in this study and are described below. A more detailed description of each program and the requirements can be found at https://www.valleywater.org/landscaperebateprogram. The programs involve pre- and post-inspections (typically on-site) to ensure that program requirements are met. The programs offer educational and technical assistance for meeting requirements via a hotline, plus videos and educational resources online.

Landscape (LND) – This program offers rebates for conversion of turf or pool areas to a landscape of low-water use species in conjunction with drip irrigation. In this study, all subjects converted live (green) turf areas only. Replacement of a live lawn to a low water-use landscape was a requirement for this rebate program during the time of this study. In 2015, replacement of dead (brown) lawns were also permitted for this rebate program; these sites were not included in the study as they would confound water saving calculations. The species selected for planting in the conversion area are required to be selected from the SCVWD's list of qualifying plants, which is adapted from the Water Use Classification of Landscape Species (WUCOLS IV) plant list (http://ucanr.edu/sites/WUCOLS/).

Equipment rebate types are described as follows. Program participants must select equipment from the SCVWD qualifying list in order to receive a rebate.

Weather based irrigation controller with rain shut-off device (WBIC+RN) – replacement of conventional automatic irrigation controller with "smart" irrigation controller that sets and adjusts water application in response to changes in the weather. These controllers are programmed to calculate plant irrigation based on weather parameters, typically measured on-site. These controllers are termed as “weather-based,” “smart,” or “ET,” and are collectively referred to by the irrigation industry as Smart Water Application Technology, or SWAT. These controllers are eligible for rebate if they contain or are installed in conjunction with on-site rain shut-off devices.

<u>High efficiency nozzles (HEN)</u> – conversion of conventional nozzles to high-efficiency nozzles.

<u>High efficiency nozzles and spray bodies with pressure regulation and/or check valves (HEN+BOD)</u> – conversion of conventional nozzles and spray bodies to high efficiency nozzles and spray bodies with pressure regulation and/or check valves.

Data Collection

This study focused on single-family residences (SFR), which comprise the largest LRP participant type. The participating SFRs included for this study were restricted to those that obtained a single rebate type (LND, WBIC+RN, HEN, or HEN+BOD), as the inclusion of combined rebates would restrict the ability to differentiate the savings due to different programs. In addition, sites were required to have at least one year of data in the pre-conversion period and one year of data in the post-conversion period.

LRP participants sign an agreement permitting their water retailers to share their water consumption data with the SCVWD for study purposes. A partnership was established with ten retailers in the SCVWD service area to obtain water billing data for this study. Copies of participant rebate agreements were provided to each participating retailer. Water billing data in units of 100 cubic feet (ccf) were obtained from each retailer for SFRs that participated in LRP from 2011-2015. Data were uniquely identified by street address. The following participating retailers provided water consumption data in a monthly format: California Water Service Company, City of Morgan Hill, City of Santa Clara, Purissima Hills Water District, and Stanford University. These participating retailers provided bimonthly water consumption data: San Jose Municipal Water System, Great Oaks Water Company, City of Milpitas Community Services, City of Mountain View Public Works, and San Jose Water Company. Each participating retailer also provided the average single family household water use in their service area in units of 100 cubic feet (CCF) for comparison to participant water use. As each retailer provided a different data format, a standard format was adopted prior to analysis.

Post-inspection dates varied between 2011-2013 for LND, 2011-2014 for WBIC+RN, 2011-2015 for HEN, and 2013-2015 for HEN+BOD, and 5, 4, 3, and 1 year(s) of post-conversion data were available for each of these programs ,respectively. Sample size varied by year, with the highest sample size being one year following conversion and declining each year thereafter. In other words, the largest group of subjects within each rebate category was in the first year following conversion.

Data Analyses

Water savings were determined in this study based on the difference between pre- and post- conversion water use for SFRs that participated in LRP from 2011 to 2015. The water billing data used in this study is based on meters that measure both indoor and outdoor water use cumulatively. Thus, an assumption of this study is that pre- and post- water use differences are due to changes in outdoor water use as a result of participation in LRP. To exclude the possibility of indoor water use changes influencing the water use differences, each SFR in this study was checked for participation in the SCVWD's water audit program known as Water Wise House Call. Through this program, inspectors replace showerheads, aerators, or toilet flappers if efficiency may be improved. If an SFR had any of these items replaced during the study period, the SFR was excluded from the study. If items were replaced after participation in LRP, the years following replacement were excluded from the study. This study does not account for other possible indoor water use changes or possible non-rebate related changes in outdoor water use.

Data were analyzed using Microsoft Excel software v. 2016 (Microsoft, Redmond, WA, USA). Pre-conversion water use of program participants was determined by averaging available water use prior to conversion. The majority of participants had 3 years of pre-conversion water use. Paired t-tests were used to analyze pre- vs. post-treatment differences. For all analyses, P-values less than 0.05 were considered significant, and p-values less than 0.1 were considered marginally significant.

Billing intervals by retailers are staggered differently for different accounts; thus, billing data were linearly interpolated at monthly intervals for individual accounts in order to obtain water use at consistent time intervals. The monthly water use values were summed to provide annual sums of water use before and after landscape or equipment conversion.

Water savings per unit was determined for irrigation equipment (WBIC + RN, HEN, and HEN + BOD), and per square foot for LND and WBIC+RN. For LND, water savings was divided by conversion area, which was measured on-site by inspectors. For WBIC+RN, water savings was divided by irrigated area, which was determined using GIS and Google Maps.

Average water use of the retailers' total SFR sector was compared to average water use of program participants to help determine whether average sector-wide data could be used to help inform study findings. Since participation in the rebate programs is low (less than 0.5% of retailers' total SFR customer base), the average SFR use is not expected to be impacted by participation. Average SFR use was expected to decrease during the study period as an increasing number of county residents reduced their outdoor water use in response to drought and allowed their lawns to die. Thus, average SFR use was expected to signal an increasing number of dead lawns and was used in this study for the purpose of comparison, rather than an experimental control. For each account, data was paired with the average SFR water use from the same retailer service area for comparison.

Results

Water savings in each year following installation are shown in Tables 1 through 4. For each year, sample size, and p-values of paired t-tests between pre-installation and post-installation samples are also shown for the years in which a suitable sample size exists. The water savings for LND were marginally significant in the first year following conversion, and were statistically significant in Years 2 through 5 following conversion. The average water savings increase incrementally each year following conversion (Figure 1). The water savings for WBIC + RN were statistically significant in the first year following conversion, and continue each year through 4 years following conversion. Similar to LND, the average water savings for WBIC + RN incrementally increases each year following conversion (Figure 2). The water savings for HEN was marginally significant in the first year following conversion, and was statistically significant 1 – 3 Years following conversion (Figure 3). The water savings for HEN + BOD was statistically significant a year following conversion (Figure 4).

Table 1: Water savings resulting from turf removal rebate program (LND), based on the difference between post-conversion water use and average of 1 – 5 years of pre-conversion water use.

Year following installation	Year 1	Year 2	Year 3	Year 4	Year 5
Water savings (gal/ft^2/y)	8 ± 4	22 ± 5	26 ± 6	28 ± 6	48 ± 9
Sample size	142	137	106	64	30
p-value of t-test between pre-installation and post-installation sample	0.0738*	<0.0001**	<0.0001**	<0.0001**	0.0003**

*marginally significant (p<0.1)

**significant (p<0.05)

Table 2: Water savings resulting from weather based irrigation controller with rain sensor rebate program (WBIC + RN), based on the difference between post-conversion water use and average of 1 – 5 years of pre-conversion water use. The water savings is shown for square footage of area irrigated by WBIC, as well as per WBIC unit.

Year following installation	Year 1	Year 2	Year 3	Year 4
Water savings (g/ft^2/y)	4 ± 2	7 ± 2	11 ± 3	14 ± 4
Water savings (g/unit/y)	22,724 ± 5839	26,403 ± 8,067	32,712 ± 9,008	38,440 ± 11,647
Sample size	84	60	35	16
p-value of t-test between pre-installation and post-installation sample	0.0002**	0.0013**	0.0010**	0.0049**

**significant (p<0.05)

Table 3: Water savings resulting from the conversion of conventional nozzles to high-efficiency nozzles (HEN), based on the difference between post-conversion water use and average of 1 – 5 years of pre-conversion water use.

Year following installation	Year 1	Year 2	Year 3
Water savings (g/unit/y)	541 ± 233	1,536 ± 337	949 ± 412
Sample size	52	40	11
p-value of t-test between pre-installation and post-installation sample	0.0626*	0.0001**	0.0291**

*marginally significant (p<0.1)

**significant (p<0.05)

Table 4: Water savings resulting from the conversion of conventional nozzles and bodies to high-efficiency nozzles and bodies (HEN + BOD), based on the difference between post-conversion water use and average of 1 – 5 years of pre-conversion water use.

Year following installation	Year 1
Water savings (gal/unit/y)	1,661 ± 701
Sample size	17
p-value of t-test between pre-installation and post-installation sample	0.0384**

**significant (p<0.05)

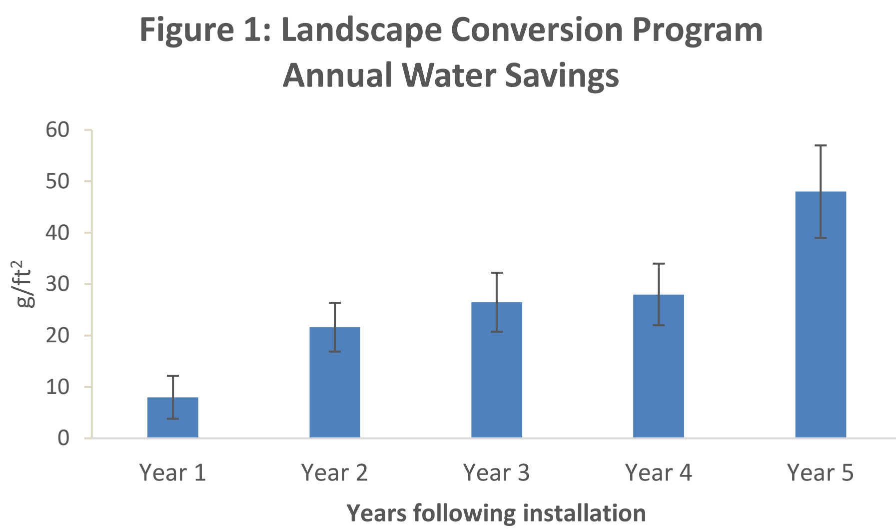


Figure 1: Landscape Conversion Program
Annual Water Savings
60
50
40
30
20
10
0
g/ft2
Year 1
Year 2
Year 3
Year 4
Year 5
Years following installation

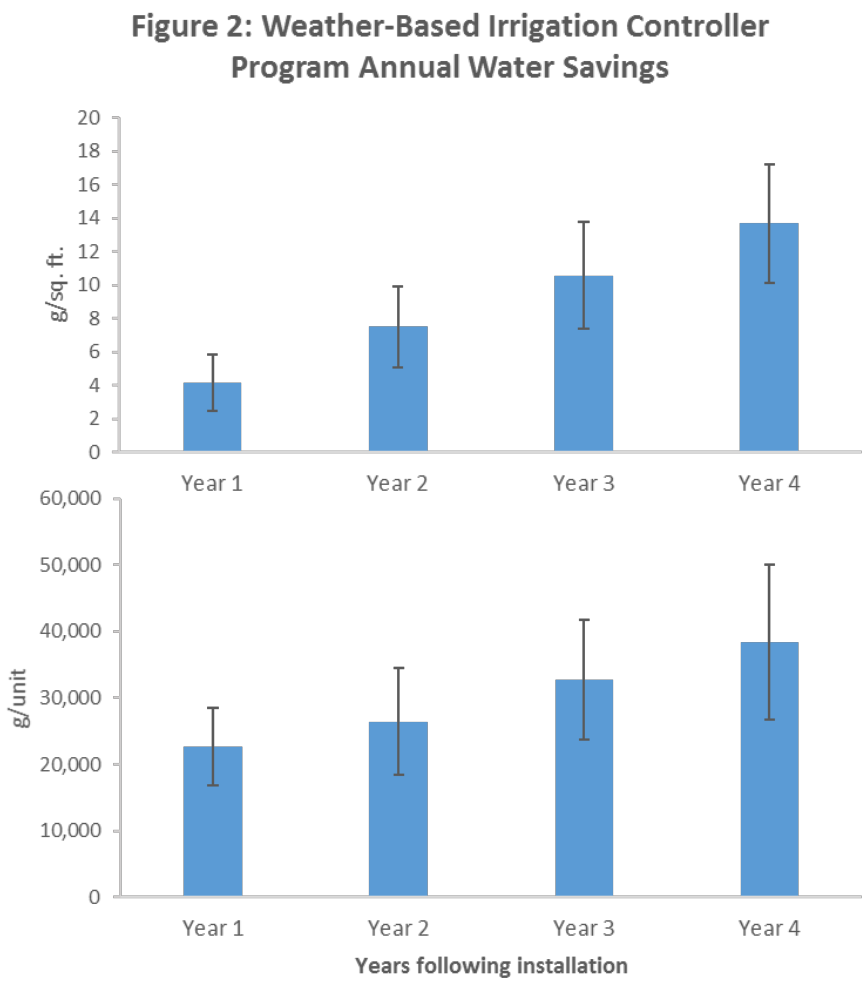
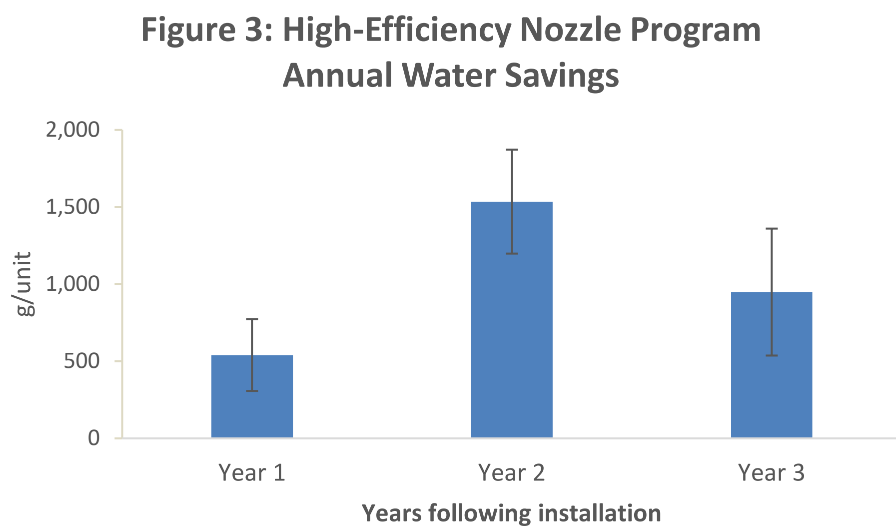
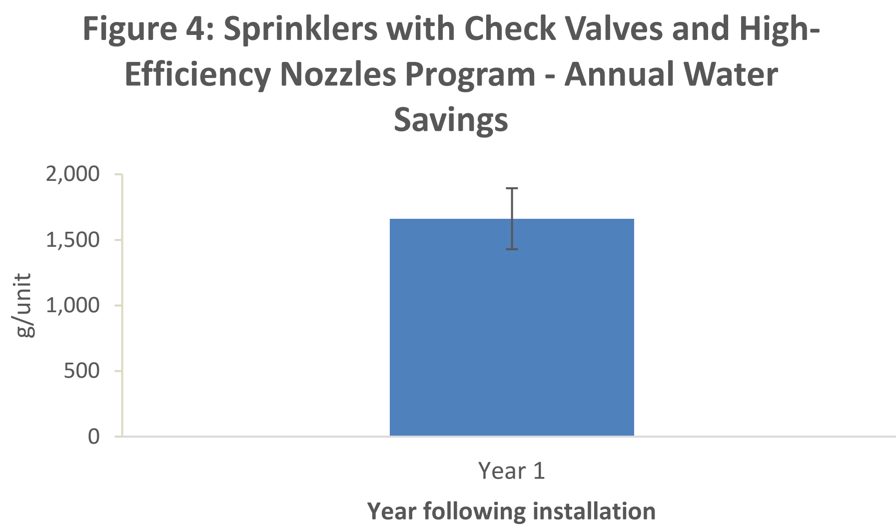


Figure 2: Weather-Based Irrigation Controller
Program Annual Water Savings
g/sq. ft.
20
18
16
14
12
10
8
6
4
2
0
Year 1
Year 2
Year 3
Year 4
g/unit
60,000
50,000
40,000
30,000
20,000
10,000
0
Year 1
Year 2
Year 3
Year 4
Years following installation





As noted above, average water use by program participants was compared to average SFR use. The purpose of this analysis was to determine whether average SFR use could be used to determine water savings associated with program participation. Tables 5 through 8 show that pre-installation water use differed between average SFRs and program participants in every case for LND, WBIC + RN, HEN, and HEN + BOD ($p = 0.0007$, $p = 0.0004$, $p = 0.0023$, $p = 0.0044$, respectively). For turf removal rebates, participants had lower pre-installation water use. For equipment rebates, participants had higher pre-installation water use. The average pre-installation SFR water use varies between Tables 5 through 8 because the pre-installation periods varied. During the period analyzed, average SFR water use declined along with declines in participant water use. The author attributes the decline in average SFR use to residents' response to the 2012-2016 drought, which included an increasing number of county residents letting their lawn brown in order to conserve water. Some may have responded to the local "brown is the new green" media campaign during the time, which encouraged people to conserve by cutting back on outdoor irrigation. Given the differences in pre-installation water use between the program participants and average SFR water use, as well as the variation in average SFR water use, average SFR use is not appropriate as an experimental control. Thus, average SFR use is shown only for comparison. Water savings was determined as the difference between pre- and post- LRP project water use.

Table 5: Pre-installation annual water use (average water use 1-5 years prior to conversion) and percentage decrease in water use for LND participants and average SFRs. Participants had lower average pre-installation water use than average single family residences within the same retailer area (p = 0.0007).

	Pre-installation annual water use (CCF)	Percent decrease in water use				
		Year 1	Year 2	Year 3	Year 4	Year 5
Participants	161 ± 9	6%	13%	18%	23%	32%
Average SFR	191 ± 5	-2%	7%	11%	19%	28%

Table 6: Pre-installation annual water use (average water use 1-5 years prior to conversion) and percentage decrease in water use for WBIC + RN participants and average SFRs. Participants had higher average pre-installation water use than average single family residences within the same retailer area (p = 0.0044).

	Pre-installation annual water use (CCF)	Percent decrease in water use			
		Year 1	Year 2	Year 3	Year 4
Participants	250 ± 17	15%	17%	20%	27%
Average SFR	205 ± 6	9%	16%	20%	29%

Table 7: Pre-installation annual water use (average water use 1-5 years prior to conversion) and percentage decrease in water use for HEN participants and average SFRs. Participants had higher average pre-installation water use than average single family residences within the same retailer area (p = 0.0004).

	Pre-installation annual water use (CCF)	Percent decrease in water use		
		Year 1	Year 2	Year 3
Participants	254 ± 19	8%	20%	18%
Average SFR	180 ± 6	10%	23%	22%

Table 8: Pre-installation annual water use (average water use 1-5 years prior to conversion) and percentage decrease in water use for HEN + BOD participants and average SFRs. Participants had higher average pre-installation water use than average single family residences within the same retailer area (p = 0.0023).

	Pre-installation annual water use (CCF)	Percent decrease in water use
		Year 1
Participants	305 ± 43	18%
Average SFR	186 ± 15	20%

Discussion

Analysis indicated water savings for each post-conversion year examined in this study for WBIC (1-4 years) and HEN+BOD (1 year). LND and HEN savings were statistically significant after the first post-conversion year, up to five years for LND and up to three years for HEN. For LND and WBIC, there was an incrementally increasing trend in average annual water savings. Further study would be needed to determine how many years the savings would continue to increase. Plant water use is expected to decrease with maturity and eventually stabilize. Thus, the water savings for LND may plateau after a certain number of years, corresponding with the time needed for the new landscape to fully establish and for maintenance practices to regularize. Annual average LND savings were up to 48 g/ft^2 (during the fifth year following conversion), and on average 31 g/ft^2 for years 2 through 5 when savings were significant. For comparison to LND savings (Table 1), the estimated annual savings in the Alliance for Water Efficiency Tracking Tool model was 36 gal/ft^2, (http://www.allianceforwaterefficiency.org/Tracking-Tool.aspx) and the estimated savings by the California Data Collaborative in Moulton Niguel are 24.6 gal/ft^2.

Surprisingly, HEN were only marginally significant in the first year following conversion, and were significant thereafter. This may be because landscapers or householders who install high efficiency nozzles may not be aware of how to properly adjust the scheduling for the new nozzles during their first year. It is recommended that with HEN rebates, the recipients should be provided information or assistance to adjust their irrigation run times following conversion to achieve the immediate savings that would be expected from HEN. Once savings from HEN were significantly achieved in year 2 (1,536 ± 337 g/unit/y) and year 3 (949 ± 412 g/unit/y), the savings do not differ much from high-efficiency nozzles in conjunction with bodies, indicating that there is not additional savings to be achieved by adding sprinkler bodies to the high-efficiency nozzle rebate.

Further study would help determine the lifetime for the water savings for each rebate type, or whether the rebates lead to a permanent reduction in water use. There was a large decline in average SFR use during these drought years. It is expected that average SFR water use would rebound in the years following this study, while participant water use remains lower.

Installation of WBICs has greater savings per unit as compared to HEN and HEN + BOD, but these savings are dependent on area utilized by the WBIC and are expected to vary based on the household's landscape area.

Interestingly, participants in the LND had lower pre-installation water use than average SFR user, which suggests that program uptake is by households already conserving water relative to others in their service area, and may be motivated by environmental ideology. For equipment rebates, pre-conversion water usage was higher for participants as opposed to the average SFR. This suggests that equipment rebates may be pragmatic or financially motivated, as these users are on average spending more on their water bills than others in their service areas.

Controlled experiments, primarily in humid climates, have shown water savings of 40-70% when using weather-based irrigation devices, but large real-world studies have shown savings less than 10% (Dukes 2012). Smart controllers may be programmed incorrectly, causing over-irrigation (Pittenger et al. 2004, Bijoor et al, 2014). They cannot reduce the irrigation rate unless sprinklers irrigate uniformly, or are adjusted to irrigate uniformly. The percentage of savings reported in this study is higher than other studies for several possible reasons. First, WBICs must be installed with rain-sensors, and this is likely to increase the likelihood of success. In addition, most previous studies of WBICs are in regions with lower reference evapotranspiration.

Conclusions

The study results indicate that significant water savings were achieved by SCVWD conservation programs involving rebates for turf removal, weather-based irrigation controllers, high-efficiency nozzles, and high efficiency nozzles with sprinkler bodies. For turf removal rebates, savings are marginal in the first year, significant thereafter, and incrementally increase. The study shows that the rebate programs offered by SCVWD have been successful in achieving significant water conservation. Beyond the adoption of new landscape and technology, other factors that may contribute to program success are SCVWD's stringent requirements (requirements for plant list, drip irrigation, and pre- and post-inspection verification) and SCVWD's capacity-building efforts (program and educational information provided by inspectors on-site, the availability of a conservation hotline to provide participants with program assistance, and detailed online program information, educational outreach, and instructional videos).

References

Bijoor, N., Pataki, D., Haver, D., Famiglietti, J. (2014) A comparative study of the water budgets of lawns under three management scenarios. *Urban Ecosystems*, 1-23.

Diffenbaugh, N., Scherer, M., Ashfaq, M. (2012) Response of snow-dependent hydrologic extremes to continued global warming*. Nature Climate Change,* doi:10.1038/nclimate1732.

Dukes, M. D. 2012. Water conservation potential of landscape irrigation smart controllers. *Transactions of the ASABE*, 55:563-569.

Executive Order No. B-29-15 (2015), accessed from https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf

Knickmeyer, E. (2016) In California, a $350 million social experiment over lawns. *AP News*, https://apnews.com/c7ac174c2aec4470ba4c416944864d01/california-350-million-social-experiment-over-lawns

Griffin, D., Anchukaitis, K.J. (2014) How unusual is the 2012–2014 California drought? *Geophysical Research Letters*, 41, 9017-9023.

Pittenger, D. R., D. A. Shaw, and W. E. Richie. 2004. Evaluation of weather-sensing landscape irrigation controllers. University of California Cooperative Extension: Riverside, CA; 26 pp.

Schmitt, E., Tull, C., Atwater, P. (2016) How Much Water Does Turf Removal Save? Applying Bayesian Structural Time-Series to California Residential Water Demand. *Paper presented to SIGKDD: Data Science for Food*, Energy and Water, San Francisco, August 2016.

Valley Water

Clean Water • Healthy Environment • Flood Protection

Santa Clara Valley Water District
5750 Almaden Expressway, San José, CA 95118-3686
Phone: (408) 265-2600 Fax: (408) 266-0271
www.valleywater.org