UC RIVERSIDE UNIVERSITY OF CALIFORNIA | School of Public Policy

Policy Matters

VOLUME 6, ISSUE 1 FALL 2014

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Coping with Water Scarcity:

The Effectiveness of Allocation-Based Pricing and Conservation Rebate Programs in California's Urban Sector

EXECUTIVE SUMMARY

California saw its driest year on record in 2013, and the drought is expected to continue into the foreseeable future. More than ever, urban water managers are seeking effective strategies to address water scarcity, with increasing interest in reducing residential water demand. To help achieve these goals, researchers at UCR's School of Public Policy have partnered with local water agencies in an effort to evaluate the effectiveness of ongoing residential water conservation programs.

Two general messages have emerged from from these partnerships to date. First, budget-based increasing block rate pricing structures can be an effective strategy for reducing per capita residential water use in a manner that can address both efficiency and equity issues confronting agencies. Second, while conservation programs, including many that have been offered by agencies to their residential customers in Southern California since the early 1990s, have been relatively successful in reducing per capita water use, any efforts to achieve further reductions in line with state mandates will likely require systematic evaluations of particular programs with the intent to better understand human behavior.

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Introduction

With 2013 as the driest year on record and the drought continuing into 2014 and the foreseeable future, urban water managers are seeking effective strategies to address water scarcity, with increasing interest in reducing residential water demand.[1] Reducing residential water demand is appealing since many of the more traditional approaches to addressing water scarcity, such as building more storage and conveyance systems to change the temporal and spatial availability of water supplies, have become exceedingly expensive, largely due to land availability and zoning restrictions as well as environmental regulations. Reducing residential water demand is also attractive given that it is a local solution to relieving water stress with seemingly much recent success.

From 1990 to 2013 for example, the portfolio of residential water conservation programs offered to rate payers in Southern California's Metropolitan Water District (MWD) service region[2] has been touted as the primary reason for the observed reduction in per capita water use from 208 gallons per capita per day (gpcd) down to 175 gpcd. Consequently, while population in the region grew by nearly 26% (3.9 million people) over that period, overall water use increased by only 5%.

State mandates, as well as simple water balance calculations, suggest further reductions in residential water use are needed. That is, the state's population is expected to increase from slightly over 38 million people in 2013 to approximately 50 million people in 2050 (Johnson, 2014). With climate change predictions suggesting a dryer California coupled with increased concern over environmental issues, the level of water scarcity will continue to rise without bold and integrative action.[3] Partly in response to these concerns, the state of California in 2010 enacted the *20x2020 Water Conservation Plan* promoting legislative initiatives and activities to require urban water supplies to establish water conservation targets for the years 2015 and 2020, with the goal of achieving a 20% reduction in per capita urban water demand by 2020 (DWR, 2010).

To better understand these challenges and to evaluate ongoing efforts to meet them, researchers in UCR's School of Public Policy have been actively engaging water agency personnel and other water professionals in inland Southern California. In June 2014, this group helped to convene the Urban Water Management Workshop, which: 1) brought together a multidisciplinary group of water managers, University of California researchers, and other water professionals; 2) spotlighted various Southern California water agency efforts to promote water conservation at the local level; 3) highlighted research findings relevant for water conservation; and 4) served as a platform for candid and frank discussion of the challenges that remain to reduce water demand further, both in the near and intermediate future.[4]

This article highlights research findings concerning two approaches that have been widely adopted by water agencies to reduce residential water demand in urban settings: *volumetric price-based conservation efforts*, and *rebate programs for residential properties* that adopt water conservation technologies. Our main goal is to help inform water managers' decision making as they work to reduce household water demand at this crucial time.[4] We also hope to expand the dialogue between water agencies and the research community, so that researchers can produce more useful and policy-relevant results through better understanding of the critical issues and factors confronting and constraining water agencies.

Approaches to Reducing Water Use

Efforts to reduce water demand by changing behavior can be categorized into *price* and *non-price* approaches. Price-based approaches focus on adjusting the price of water while non-price approaches include all other demand management strategies. One popular non-price approach involves changing behavior by promoting adoption of water conserving technologies, including fixtures such as low-flow shower heads and low-flush toilets, front-loading washers, or outdoor irrigation controllers. Agencies often offer monetary incentives in the form of rebates to households to encourage water users to adopt such technologies.[5] Research by Olmstead and Stavins (2008) suggests that technological adoption is often motivated more by environmental attitudes than by any financial incentives offered by the agency. Obviously, as the price of water rises, the cost savings from adopting water conserving technologies also increase, and households become more likely to adopt regardless of other rebates that might be offered. Other nonprice-based approaches include voluntary appeals, mandatory restrictions, information, and education. These may come in the form of rationing, school programs, flyers, moral suasion (the act of influencing behavior by referencing one's moral responsibility for the good of society)[6], as well as social norm messaging (highlighting and comparing one's behavior in relation to others, with the goal of inciting behavioral change).

Price-based approaches alter demand and behavior through direct changes in the price of water. As economic theory and evidence suggest, as the relative price of a good increases, the quantity demanded for that good generally decreases. Price-based instruments for water management, as discussed below, have proven to be very effective when compared to non-price instruments. While there are many different types of price-based structures that can be used by water agencies, two of the most popular include a uniform rate structure and an increasing block-rate pricing structure (sometimes referred to as increasing tiered-rate pricing). Under the uniform rate structure, a constant price is charged for each unit of water consumed. Under the increasing block rate structure, as the quantity of water consumed increases, the price per unit of water increases in a step-wise manner. In other words, consumption is divided into volumetric "blocks," each with its own price level. The first block is typically intended to cover basic human needs and is priced at a very affordable level. The second block often is intended to cover outdoor irrigation needs, and is priced somewhat higher. Subsequent blocks have even higher prices that provide stronger incentives to conserve water.

One particular type of tiered water rate structure that currently is generating interest and being applied by several water utilities in Southern California is a budget-based (or allocation-based) increasing block rate price (IBR) structure, hereafter referred to as a "water budget." Under a water budget, block sizes are based on household specific characteristics (e.g., household size, irrigated area, special needs), environmental conditions (e.g., evapotranspiration), and a judgment by the water utility as to what constitutes "efficient" water use given those characteristics and conditions. In most cases, water budgets are defined as an indoor allocation based on the number of people in the house and an outdoor allocation based on the amount of irrigable land, special needs, and local weather conditions. The sum of the indoor and outdoor allocations is defined as a household's water budget, and staying within that budget is deemed "efficient use." Similar to standard block pricing, water budget pricing consists of a low unit price charged in the first block and a slightly higher price in the second block. Water use that exceeds a household's budget is considered inefficient, and is thus priced at a higher rate to encourage conservation. As the next section illustrates, recent empirical evidence within southern California suggests that this sort of pricing structure can be very effective for reducing residential water demand while securing the financial cashflow of the water utility.

Effectiveness of Budget-Based Increasing Block Rate Pricing

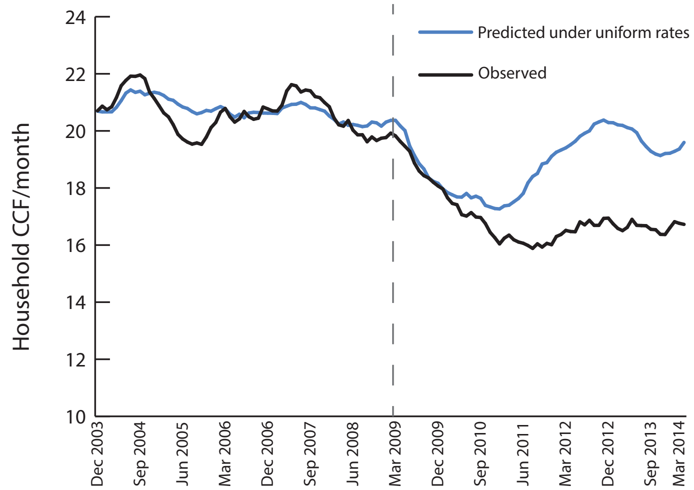
While water budgets are not widely used in the United States, we are starting to see more uptake of this pricing structure, particularly in Southern California.[7] For example, Irvine Ranch Water District in Southern California was one of the first adopters of this structure, instituting it in the early 1990s. As of 2011, over twenty-five water utilities in California had adopted water budgets (Baerenklau et al., 2014b). While each year brings more agencies adopting water budgets, concern does exist over the legality of the prices in the inefficient blocks, and the potential cost incurred in implementing such a system in which more information about household characteristics and environmental conditions are required.[8] In addition, water agencies are also concerned with the political economy/equity of its implementation and achieving agency's financial stability.[9] While these issues are clearly important for agencies to consider, this article focuses on the conservation potential of the rate structure.

One agency that recently implemented water budgets is the Eastern Municipal Water District (EMWD) of Southern California, which adopted budget-based pricing in April 2009. Serving a region covering 542 square miles with a population of over 768,000, EMWD utilizes a rate structure with four blocks: (1) efficient indoor use; (2) efficient outdoor use; (3) excessive use; and (4) wasteful use. The switch from uniform rates to increasing block budget-based rates has proven to be an effective water use reduction tool for EMWD.

To estimate the effect of EMWD's rate structure change on household water demand, we focused on 12,065 single-family households (with no changes in tenancies), a number which accounts for around 9 percent of EMWD's total served residential households. We reviewed continuous monthly water use records provided by EMWD from January 2003 to April 2014. Based on the data from 2003 to 2008, we created a statistical model of household demand under uniform pricing, where demand is estimated as a function of evapotranspiration requirements, water price, household income, seasonal factors, an annual time trend, appeals by EMWD for increased voluntary conservation, and other relevant household characteristics that are assumed not to change through time.[10] We used this model to predict household demand, had EMWD maintained a uniform pricing structure from 2009 to 2014, with prices set equal to the average prices paid by households under the budget-based rates. We then compared these predictions with the observed household demand under the allocation-based block rates and attributed the difference between the predicted and observed values to the conservation effect of the new rate structure.

We found that between July 2011 and April 2014, household usage was 10-15% lower than it would have been under equivalent uniform rates (Figure 1). Initially, one year after the switch to allocation-based rates, there was minimal observable effect on household demand. However, two years after the switch, water

Figure 1. Comparison of observed demand against model predictions



Vertical dashed line indicates the date when the water budget IBR price structure was implemented.

use per household dipped by 10 percent in comparison to where it would have been had EMWD continued its uniform pricing structure. Subsequently, the demand effect has largely remained stable at around a 10 to 15 percent reduction for the past three years. Moreover, the largest reductions came from households who were relatively inefficient users before the pricing change (25-30% reduction) while the relatively efficient households had more modest behavioral changes (roughly 5-10% reduction). We also used our model to predict what EMWD would have had to charge for water to achieve a 10 to 15% reduction in water use under the uniform price structure. Our results suggest that the average price for water would have had to rise by around 30 percent to meet the same reduction in water demand, whereas average prices rose only a few percent under budget-based rates.[11]

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Despite this effectiveness in reducing demand, a concern about implementing budget-based water rates is the potentially negative impact on low-income households. However, the households in our study that had relatively lower incomes actually experienced a decrease in average water prices paid under the budget-based rates, as well as a decline in usage. Such an outcome is perhaps in response to the unwanted possibility of having to pay the higher prices in the upper tiers. This result suggests that implementation of budget-based IBR's are not necessarily incompatible with efforts to promote equity across income levels.[12]

Although these results are promising, additional time and analysis is needed to fully understand the effects of EMWD's rate structure on reducing water use consumption, as well as to evaluate the robustness of these results across agencies. Yet for now, a key takeaway is that there is strong evidence that IBR water budget pricing is an effective price-based instrument for achieving lasting reductions in household water demand.

Effectiveness of Rebate Programs

Even though price-based measures like that utilized by EMWD seem to be effective, non-price measures seem to fall short of initial estimates (Olmstead and Stavins, 2008; Dupont, 2014). For example, using data from 13 groundwater-dependent California cities, a comparison of mandatory low-flow appliance regulations against modest water price increases showed that in almost all cases prices were more effective (and cost-effective) than technology standards in curbing water consumption (Timmins 2003). Another study in Perth, Australia showed that restrictions on use of sprinklers led to more overwatering from hand-held hoses, resulting in little water savings and additional costs to the household (Brennan et al. 2007). And a comparison of the effectiveness of mandatory restrictions to water prices in Sydney, Australia found that mandatory water restrictions resulted in costly and inefficient responses relative to prices (Grafton and Ward 2008).

At the same time, social norm-based messaging programs have been garnering significant attention from water agencies. Under these non-price instruments, residential households are given information on water use of similar households within their water districts with the idea that for those households that are above the average of their cohort group, such information would lead to a reduction in water use. Reasons why households would feel compelled to reduce their water usage should their consumption be above the include: knowledge that such reductions are feasible for similarly characterized households, and pressure to conform.

Two studies that have investigated the effectiveness of social-norm messaging on water use include a series of papers by Paul Ferraro and co-authors (Ferraro et al., 2011; Ferraro and Price, 2013; Bernedo et al., forthcoming) investigating the results of a controlled experiment with a water district and its customers in Atlanta, Georgia; and Chestnutt and Mitchell (2013) who evaluated the effectiveness of a private sector social messaging service in the East Bay Municipal Water District (EBMUD) in Northern California. While the specifics and design of each study differ in significant ways, both observe approximately a 4 to 6% reduction in water use following the "message." In the Ferraro et al. studies, which use a single message with no follow-up messages, reductions in water use were cut by nearly 50% one year after the intervention. However, a statistically noticeable difference relative to the control group still exists 6 years after the intervention. The persistence in their results suggests that this approach is relatively cost effective with an estimated $0.24 per thousand gallons saved. Furthermore, if the agency would have targeted water users consuming at or above the median user, they would have achieved nearly 88% of the overall savings for only 66% of the costs. Another noticeable outcome of their study was that the households with the largest reductions were those with the highest incomes, an important issue given that higher-income households are typically less price sensitive than lower income households.

Mitchell and Chestnutt's (2013) study of EBMUD's implementation of "Home Water Reports" by WaterSmart Software showed an approximate 5.6% reduction in water use immediately following the initial delivery of the reports. In the EBMUD study, the reduction was persistent throughout the year as the reports were given each month. This study also found that there was no "boomerang" effect by households that were under the average indicated on their report (i.e., they did not increase their water usage when given notice that they were using less than their "neighbors"), yet there was an "uplifting" or "ratcheting" effect whereby households that were given these reports were observed to increase their participation in other conservation programs relative to the control group.

Other types of non-price approaches, including rebate programs, have shown smaller than anticipated water savings (Olmstead and Stavins 2007). This is mostly due to incorrect assumptions regarding behavior, including failing to account for a *"rebound effect"* whereby households respond to improved water efficiency by changing behavior to increase overall water use. Dupont (2014) lists a number of examples from the literature where this has been observed, including research by Mayer et al. (1998) that show that low-flow showerheads tend to result in longer showers and low-flow toilets tend to result in more flushing, and Davis (2008) who shows that front-loading clothes washers tend to result in more cycles. As Dupont (2014) points out, studies of households that are fitted with low-flow fixtures overall have shown mixed results—low-flow toilets save 6.1 to 10.6 gallons per capita per day in some studies compared to no savings in others, and low-flow showerheads save anywhere from 0 to 9 percent.

In addition to the rebound effect, *"additionality"* also plays a role in the cost-effectiveness of rebate programs. Additionality refers to the question of whether customers would participate in such programs without the rebates as incentives. If they would, then the rebate program produces little additional conservation. A recent study by Bennear and Taylor (2013) of a North Carolina rebate program for low-flush toilets showed that while the program seemed to reduce household water use by 7% annually, only about 33% of these savings could be attributed to the rebate program; the other 67% likely would have been achieved anyway by households purchasing low-flush toilets in the near future without such a rebate. As such, the program cost approximately $11 to $15 per 1000 gallons of water saved, which is more costly than a number of other programs being run by the agency that cost approximately $7 per 1000 gallons saved. However, the authors calculate that if the agency had been able to target only those households that required a rebate to adopt low-flush toilets, the cost of the program would have been reduced to approximately $4 per 1000 gallons saved.

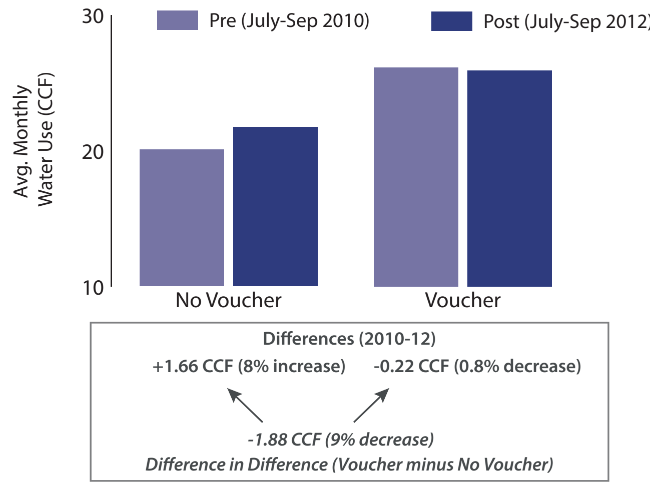
Given the importance of better understanding when and where non-price conservation measures might be effective, we partnered with Western Municipal Water District (WMWD) in

Southern California to evaluate the effectiveness of their high efficiency sprinkler nozzle rebate program.[13] Under this program, households may obtain free high efficiency sprinkler nozzles from their water agency after watching an online video about how the nozzles and the program work. Engineering estimates suggest that the nozzles may lead to significant outdoor water savings via improved irrigation efficiency. Our goal was to determine which factors influence whether households participate in the program and, if they do participate, what is the expected water savings. A better understanding of the factors that motivate program participation or technology adoption can help agencies achieve a more cost-effective implementation of these programs; a better understanding of the outcomes can help agencies determine whether the programs are worthwhile. However, a challenge we faced was that there is no information on whether participating households actually install the sprinkler nozzles, or whether they install them correctly. Rather, we only know whether a household redeemed a voucher for free nozzles at a local distributor. While in the future we hope to work with the agencies and conduct a household survey to assess nozzle installations, it is still informative to investigate the determinants of participation (voucher redemption), as well as whether participation produces a discernable reduction in water use.

For this study, we utilized household level data collected for the EMWD block rate study.[14] Specifically, we analyzed monthly water use data supplied by EMWD on 91,151 households from April 2009 to September 2012, including 1,211 households (which accounts for 1.3% of the total households serviced by EMWD) that redeemed vouchers between October 2011 and June 2012. We found that households with higher incomes, more household members, more landscaped area, and higher water usage were more likely to participate in the program; while households with higher evapotranspiration requirements and that are located further from the nozzle distribution centers were less likely to participate. This sort of information, while preliminary, is useful for agencies in their efforts to identify and more effectively target those households that have a higher propensity to participate in conservation programs.

Next we investigated the impact of participation on water use, where again we cannot directly observe whether the household properly installed the sprinklers. To do this, we first implemented a common statistical method called a "difference in differences" analysis. Specifically we compared the summertime average water use by households that redeemed vouchers versus those that did not, both before (summer 2010) and after (summer 2012) the program (Figure 2). Over this period—from 2010 to 2012—average summer water use increased by approximately 8% for those households that did not redeem vouchers. Conversely, for households that redeemed vouchers, average summer water use decreased by approximately 0.8%. The difference between these two observed changes in water demand, which is approximately 9%, is an estimate of the effectiveness of the sprinkler nozzle program.

Figure 2. Water Use Pre- and Post-Phase II Program Period*



** EMWD's Phase II Program—offering vouchers for high efficiency sprinkler nozzles ran from 10/2011 to 6/2012. Total accounts ~91,151; Accounts redeeming vouchers ~1,211.*

A potential drawback of this approach is that it does not account for the demand effects of household characteristics that might differ between these two groups and that might also have been changing during this time period. To address this possibility, we modified the block rate water demand model developed in Baerenklau et al. (2014a) to include program participation as an additional explanatory variable. Depending on one's assumption as to when households might have installed the sprinkler nozzles following voucher redemption, we estimate summertime demand reductions ranging from 2.8% up to 8.9%.[15]

While research continues on this project to address measurement and selectivity issues, it is interesting to note a few additional observations. First, and in terms of usage, the largest reduction in water use between 2010 and 2012, both in percentage and absolute terms, came from high usage households that redeemed vouchers. Over the same time period, and in considering how the voucher program may have affected households across different income categories, we find that households in the lower tercile of income that redeemed vouchers accounted for the largest *percentage* reduction in water use, and households above the 50th percentile of income who redeemed vouchers had the largest reduction in *absolute* water use.

Our analysis highlights the potential benefits of partnerships between agencies and the academic research community as well as the need for more information to make accurate assessments regarding the effectiveness and costs of any particular conservation strategy.

These findings, while preliminary, illustrate how a systematic evaluation of these programs can shed light on who is participating and the potential impact of such participation. This information can be useful for agencies in considering how to more effectively target their programs by providing information on the likelihood and extent of adoption within their districts, as well as highlight the potential response by households which can be useful in considering the cost-effectiveness of programs and their contribution toward meeting local, regional, or statewide mandates. Finally, our analysis highlights the potential benefits of partnerships between agencies and the academic research community as well as the need for more information to make accurate assessments regarding the effectiveness and costs of any particular conservation strategy.

Conclusion and Future Research Directions

Efforts to address drought and reduce water scarcity within urban environments require consideration of both supply and demand side factors. With a history heavily devoted to large infrastructure projects to shore up *supply* - including investments in storage and conveyance - lower cost opportunities likely exist on the *demand* side.

The research we review in this article highlights two general themes. First, budget-based IBR pricing is an effective approach to encourage water conservation. Furthermore, switching from uniform to budget-based rates does not necessarily penalize households with low incomes or that had previously been relatively efficient water users. Second, providing incentives such as rebates for retrofitting households with water-efficient technologies have shown mixed results in terms of reducing water use, especially when compared to price-based approaches. This does not mean that such measures should be abandoned, but rather suggests that achieving real water savings in a cost effective manner requires more research and partnerships between agencies and the research community to find an optimal mix between these two approaches.

Such partnerships are particularly timely in light of the renewed interest by the state of California and local agencies in conservation measures as a means to address water scarcity and drought. For instance, in February of 2014 the MWD Board of Directors, in lockstep with the governor's statewide call for more conservation, doubled MWD's annual conservation and outreach budget from $20 million to $40 million (MWD, 2014a). Numerous conservation programs will receive a financial boost in terms of available subsidies, including doubling the rebate for turfgrass removal from $1 to $2 per square foot of turf removed, and more funding for both the residential low-flush toilet program and rain barrels (MWD, 2014b). Similarly, the Santa Ana Watershed Project Authority (SAWPA) submitted a proposal titled, "Transformational-Focused Water Use Efficiency" for $12 million in funding from the California Department of Water Resource's (DWR) 2014 Drought Grant Solicitation program.[16] As of September of 2014, DWR has recommended that the full amount be awarded. This funding, which will be matched by local water agencies who want to participate in the program, primarily focuses on providing support (or matching funds) to SAWPA agencies interested in implementing water conservation programs, including turfgrass removal and water budget rate structures.

While simply providing more money for a wide range of programs may achieve some level of conservation, it is unlikely to be cost-effective without proper oversight and evaluation. As past research indicates, efforts to implement more cost-effective programs must consider issues related to additionality, rebounding, and uplifting. Furthermore, a better understanding of customers' preferences and propensities to participate in particular programs will help agencies develop more targeted and effective programs and likely lead to greater returns per program dollar spent. The academic research community is well-trained to evaluate the behavioral issues that are important for understanding water conservation, and to deliver such analyses. Yet without insight, guidance, and input from agencies, the research community may miss its mark, which is why developing stronger partnerships among water agencies and the academic research community is a critically important and mutually beneficial endeavor.

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Notes

[1] In eleven of the past sixteen years California has experienced below normal rainfall, and four of the driest seven years since 1897 have occurred in the 2000s. As this article goes to press, the federal Climate Prediction Center forecasts that California will again experience above-normal temperatures to further stress state water resources as the state enters its fourth year of drought (Bartholomew, 2014).

[2] MWD is California's largest water agency servicing 26 cities and approximately 17 million people.

[3] Over the past 40 years, warm season duration (i.e., warm periods without sizeable rainfall) has increased by 6.4%, or approximately 15 days, within California and Nevada (Groisman and Knight, 2008).

[4] For more on the details, discussions, and presentations surrounding this workshop, go to http://wspc.ucr.edu/events/PresentationsUrbanWater.html.

[5] While periods of drought serve as a good natural experiment to consider such approaches, changing the way water is handled in a drought-prone state should become a social norm.

[6] Some researchers include rebate programs in the price-based category given that they do include, for example, changing the relative price of the technology to encourage adoption. For this paper, we treat technology-based approaches as a non-price instrument since technological adoption may occur with or without monetary incentives.

[7] Some districts use labels for households that appear to be using more water than is considered "efficient." For instance, in Eastern Municipal Water District in Southern California, households are assigned a water budget, and those that go beyond their water budget find themselves in categories labeled "excessive use" and "wasteful use."

[8] For a detailed description of how water budgets are designed or calculated across districts, see the examples provided by Irvine Ranch Water District (IRWD 2013) and Moulton Niguel Water District (MNWD 2014).

[9] For a coherent discussion of the legal issues surrounding implementation of water budgets, see Hildebrand et al. (2009).

[10] For a recent experience of the Western Municipal Water District of Southern California that relates to efficiency, financial stability, legal, and political aspects of the water budget, see Barr and Ash (2015).

[11] See Baerenklau et al. (2014a) for a detailed discussion of the model and results.

[12] *Ibid.*

[13] Information on the details of this program can be found at http://www.freesprinklernozzles.com/

[14] WMWD manages the sprinkler nozzle rebate program for several agencies, including EMWD. This analysis examines Phase II of the program within EMWD's retail area.

[15] We assume three different installation periods: the month in which the vouchers were redeemed (2.8%), two months following redemption (8.9%), and four months following redemption (4.9%), where the numbers in parenthesis indicate the estimated reduction in in average monthly summertime water use.

[16] SAWPA is a Joint Powers Authority classified as a special district to carry out useful functions to its member agencies. For information on SAWPA, see www.sawpa.org/.

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VOLUME 6, ISSUE 1 FALL 2014

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Coping with Water Scarcity:
The Effectiveness of Allocation-Based Pricing and Conservation Rebate Programs in California's Urban Sector

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